VOLUME 10 • NUMBER 11 • NOVEMBER, 1939

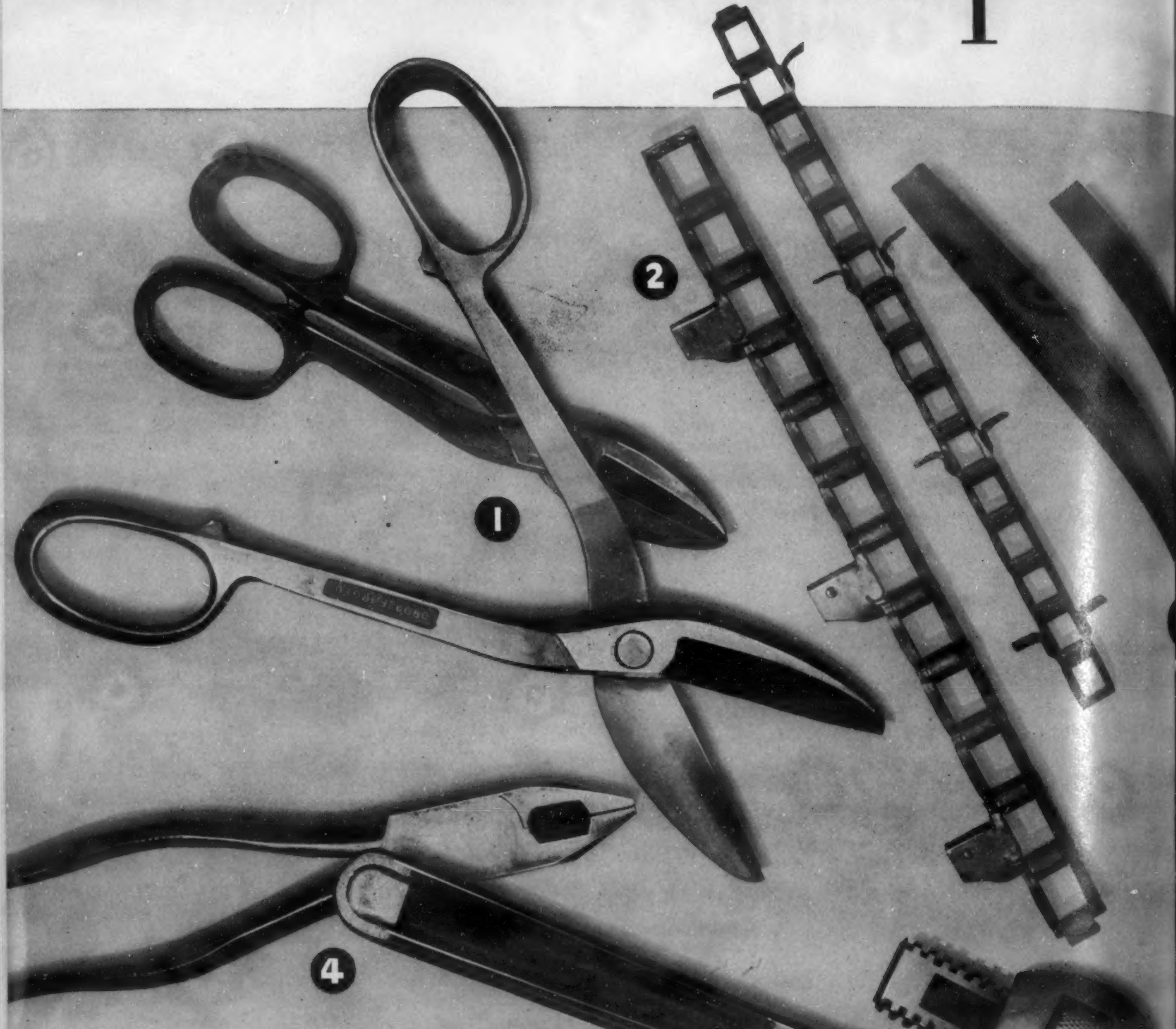
Metals and Alloys

Published Monthly by Reinhold Publishing Corporation, East Stroudsburg, Pa., U.S.A. Ralph Reinhold, President and Treasurer; H. Burton Lowe, Vice President and Secretary; Philip H. Hubbard, Vice President; Francis M. Turner, Vice President. Executive and Editorial Offices, 330 West 42nd Street, New York. Price 25 cents a copy. Annual Subscription: U. S., Possessions and Canada, $3.00. All Other Countries, $3.00. (Remit by New York Draft). Entered as second class matter June 12, 1934, at the Post Office at East Stroudsburg, Pa., under the Act of March 3, 1879.

Articles

Metallurgical Abstracts

Is there a Skeptic



We Quote These Facts

1. "Using U·S·S Controlled Steels, these tin snips have been easier to forge. In addition, the drilling operation has been more satisfactory, and heat treatment has been more uniform. Better tapping, grinding and polishing practice has been possible."

2. "U·S·S Controlled Steels have increased the physical properties of our formed and heat treated chain by at least 25%. We find the steel for our requirements is now at a very high standard of quality and of dependable uniformity."

3. "Since using U·S·S Controlled Steels there has been far more uniformity in all the processing operations, and many troubles have been eliminated. Better cutting of teeth, and hardening with less breakage and warpage are characteristics of the use of U·S·S Controlled Steels."

4. "In making Stillson wrenches performance has proved U·S·S Controlled Steels far superior for uniformity—has given these wrenches the ability to meet practically double the strength requirements. Made of U·S·S Controlled Steels, side cutting pliers have shown greater strength and longer life. Response to case carburizing and heat treatment has been excellent."

5. "U·S·S Controlled Steels, used for connecting rods, have proved advantageous in many ways. Ease of forging, uniformity in heat treatment and well-filled sections are characteristic. Also, freedom from trimmer cracks and quench cracks was noticeable, as well as marked toughness after heat treatment."

6. "With U·S·S Controlled Steels reruns on ring gears have been considerably reduced, the majority now being rerun for size only. Satisfactory performance has been noted with both fine and coarse grain steel, grade selected according to definite requirements."

UNITED

editorial

Man Bites Dog

It calls for something more than a box-heading at the top of the article when an editor has the experience we had with one of the articles in this issue. The Climax Molybdenum Co. forwarded the report on which Newell's article, page 342, is based, with the suggestion that it might make a useful article.

The reader will note that the results of the careful work by Norton at M.I.T. for Babcock & Wilcox and Climax show that the beneficial effect of 0.50 to 0.75 per cent Mo on the creep resistance of 5 per cent Cr steel is not sufficiently augmented by raising the Mo to 1 or 1.50 per cent, to justify the increase. There is nothing unusual in that a firm like Babcock & Wilcox, concerned with the engineering balance between cost and performance, should determine such facts and publish them as general engineering information. But that a producer of a basic alloying element should be eager to publicize that enough of that element is enough, is worthy of note.

This shows the sensible long view that the permanent utilization of a material is better advanced when the producers have the interests of their customers at heart than when they exert sales pressure by which the unknowing user is persuaded to use more than he needs. When the high-pressured customer does find out the facts and wakes up to the situation, he has a feeling of resentment that impels him to seek for a complete substitute. When the producer takes the attitude that his product must win its place purely on the basis of its engineering merits, and goes out of his way to prevent wasteful use, a feeling of good will and confidence is built up that is as real an asset as any other in the balance sheet.

In some other case, when experiment shows that the percentage of "moly" might advantageously be raised, and Climax so reports, the reader will believe them, because of this earlier example of square shooting.

The slogans for moly, "the friendly fraction," and "a little does a lot" are not only in accord with engineering facts, but they strike us as excellent sales psychology.—H. W. G.

Copper in Steel Castings

Copper was once a *bete noir* to the steel foundryman. Some years ago we were engaged in directing the production of acid open-hearth steel for steel castings. The presence of as much as 0.25 per cent copper in the low-phosphorus pig iron used was cause for rejection. If there were any defects in the castings, there was always an argument that the copper present (if any) was the cause.

Whether one calls the Ford alloys steel or not, the large use of copper in those alloys produced a receptive attitude among metallurgists and engineers for copper in regular cast steels.

Today the situation is radically different. Copper is now regarded as a desirable alloying element for steel castings. This has been established both by careful research and by experience, such as that recorded by Finlayson in METALS AND ALLOYS, Vol. 8, Sept. 1937, pages 239-244. More data and experience are steadily being accumulated. One needs only to have heard, or to read, the excellent paper—"Properties of Some Copper-Bearing Cast Steels"—presented at the annual convention of the American Foundrymen's Association at Cincinnati. It is a discussion of the results of an extensive research at Battelle Memorial Institute by C. T. Greenidge and C. H. Lorig. Effects of copper contents up to 2.40 per cent, with or without other alloying metals, are discussed, and it is conclusively demonstrated that, with suitable heat treatments, the copper decidedly increases certain physical properties. An added advantage, not possible with the use of some other alloying elements, is the precipitation hardening property bestowed by the copper. It is of interest to note that the first recognition of this, by Kinnear, reported in *The Iron Age,* Vol. 125, 1931, p. 696, was in cast steel.

In this connection one must not forget that, in the wrought low-alloy, high strength steels, copper is an established alloying constituent of most of them, conferring beneficial strength-giving properties, as well as the long-recognized resistance to atmospheric corrosion.

Truly as to steel castings, the reversal of trend in less than 25 years has been complete, due to persistent metallurgical research.—E. F. C.

Heat Treatment in the

BY EDWIN F. CONE

FOR SOME TIME it has been the practice of the Ford Motor Co., at its plant at Dearborn, Mich., to prepare and heat treat its tools and dies in various scattered departments. Great numbers of these implements are used daily in such a large plant. Realizing that, as the plant grew in size and in diversified operations, at least a partial concentration of these operations would be a decided advantage, there has recently been constructed a large tool and die shop in which there is a complete heat-treating or hardening department. This entire building is generally exclusive of maintenance work.

The advantages are evident—a concentration of this work in one central department, the assemblage of diversified equipment to carry out any practice, a standardization of hardening or heat-treating procedure, greater facility and efficiency in turning out work, and so on.

The object of this article is to describe the tool hardening department, including the various types of equipment, and in particular to give the heat-treating practice as developed by Ford metallurgical engineers, with some facts about the tool and die shop as a whole.

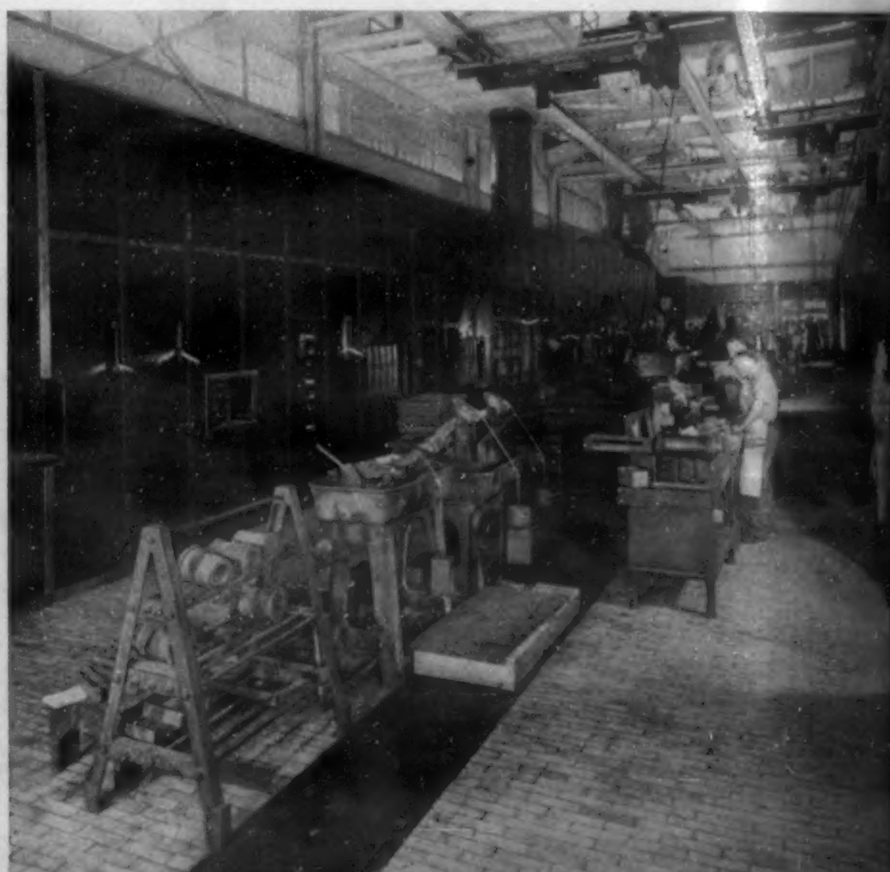
The Heat-Treating Department

Along the middle portion of the west side of the new building, which houses the machinery for forming and preparing the tools, dies and machines, is the special heat-treating or hardening department, situated in a specially enclosed room.

On one side, the outer portion, of this department are the various types of furnaces for heating the tools and dies. In the complete line there are 17

General exterior view of Tool and Die building, which is 300 ft. wide, 1225 ft. long, with new monitor-type construction for better "no-shadow" lighting.

A section of the hardening room.



Ford New Tool and Die Shop

furnaces. These are arranged in groups: One devoted solely to high-speed steels; another specially fitted for broaches; and the third a group of miscellaneous furnaces for a variety of heat-treatments depending on the material to be treated—carbon tools or dies, alloy tools or die steels.

Furnaces for High-Speed Steels

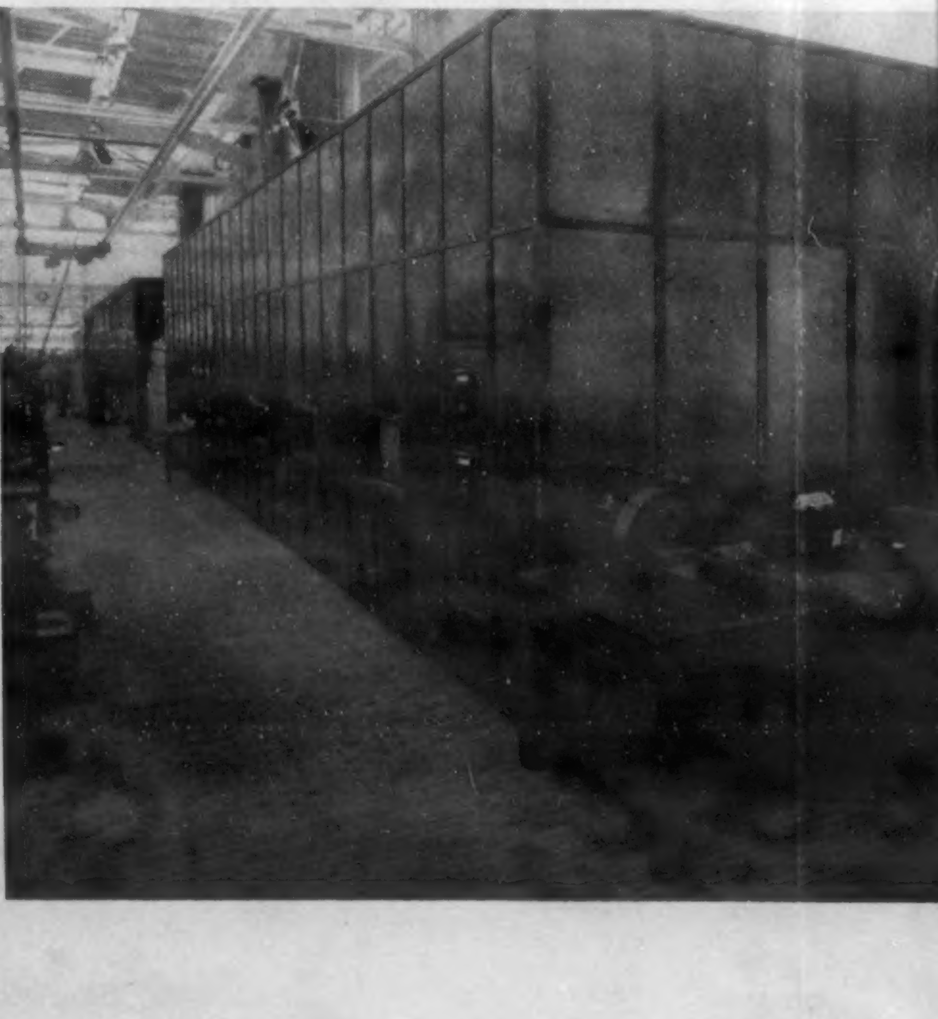
For heat treating high-speed steels, there is provided a set-up in one corner of this department of three furnace units. One is a Hayes unit consisting of a pre-heat furnace with ribbon resistors and a superheat furnace with Globar resistors. These furnaces are atmosphere controlled. The second unit is a Surface Combustion equipment consisting of a preheat furnace for temperatures up to 1900 deg. F., and a superheat furnace for temperatures up to 2500 deg. F. Both are muffle-type, gas-fired, and atmosphere controlled. The third unit is of the Bellis salt bath type, consisting of compartments for pre-heat, superheat and quench.

Adjacent to this battery of furnaces for high-speed steel are two furnaces for heat-treating broaches. They are furnished by the Standard Fuel & Engineering Co., of Detroit, and are fired with coke-oven gas as produced by the Ford ovens. The smallest will accommodate a 4-ft. and the largest a 6-ft. broach. These units are interchangeable and can be used for pre-heat or superheat up to 2300 to 2400 deg. F.

All superheating furnaces in the high-speed steel department are equipped with the Ardometer or radiation type of temperature indicators. Beside the equipment already described, there is one gas-fired and one electric furnace, without controlled atmosphere, both used for drawing. They are equipped with automatic temperature control.

Close-up of hardening room with employe taking die section out of a chrome non-shrink furnace.

General view showing Wellsford steel enclosure for heat-treating furnaces. Housing is insulated and air-conditioned to maintain the outside surface at a temperature only slightly above room temperature.



Closeup of a workman spotting-in a die on a 30-ton Baldwin-Southwark spotting press.

Close-up of Wellsford steel enclosure showing stainless steel trim.

General interior view of Tool and Die Shop looking north, with gage department in foreground and tool, jig and fixture department in background.

General view of Tool and Die Shop showing broach and cutter division beyond the aisle; also a 50-ton crane with 15-ton auxiliary hook.

This assortment of different types of furnaces—electric, gas, salt—reflects the attitude and the experience of Ford metallurgists. Different methods of heating are necessary to meet varying conditions which arise in heat treating high-speed steel—one method is better suited than another for one type of steel or tool. Hence a variety of furnaces to meet any and all conditions.

Experience of Ford metallurgists and heat-treating experts has resulted in the adoption, for the most part, of the 18-4-2 type of high-speed steel for cutting tools. The 18-4-1 is used for some purposes, usually drills. It may also be stated that the molybdenum type is also used quite liberally. The salt bath furnace is primarily used for treating this steel.

High-Speed Steel Heat-Treating Practice

The heat-treating practice which has been adopted for treating high-speed steel, whether 18-4-2 or 18-4-1, based on experience over a number of years, is briefly as follows:

The material is pre-heated at 1450 to 1500 deg. F., then superheated at 2350 to 2400 deg. F., followed by quenching in oil for small tools and in air for large tools. This is followed by a double draw of 3 hrs. minimum each, at about 1050 deg. F., air-cooled in each case.

For certain types of tools such as tool bits, forming tools, certain types of broaches and cutters where breakage is not encountered, a special heat treatment is used: Pre-heat to 1450 to 1500 deg. F., then superheat to 2350 to 2400 deg. F., air cool to 700 deg. F. This procedure is repeated and followed by a quench in oil. Then the double draw, as above, is applied. It is claimed that this practice insures a better cutting tool at the expense of some toughness —it is more brittle. In partial defense of this practice,

View of a 50-ton Baldwin-Southwark spotting press.

other tools such as stellite, carbides, etc. are more brittle. The fracture of the double-treated high-speed steel has a flaky appearance, sometimes called "fish scale."

The practice for the Mo-max types of steel is quite similar to that for 18-4-2 or 18-4-1, except that the temperatures are somewhat lower.

Other Furnace Equipment

Occupying the remainder of the side of the hardening department, next to the high-speed heating furnaces and the broach units, is a row of some eight furnaces of various types, gas-fired and electric—Hevi-Duty, Westinghouse, Standard Fuel & Engineering, Hayes, Holcroft and so on. Some of these are used for bringing the tool steels up to temperatures for hardening and are atmosphere controlled. Some are employed in drawing or normalizing operations and are not atmosphere controlled. Temperatures are controlled by recording pyrometers. So much for the heating equipment and operations.

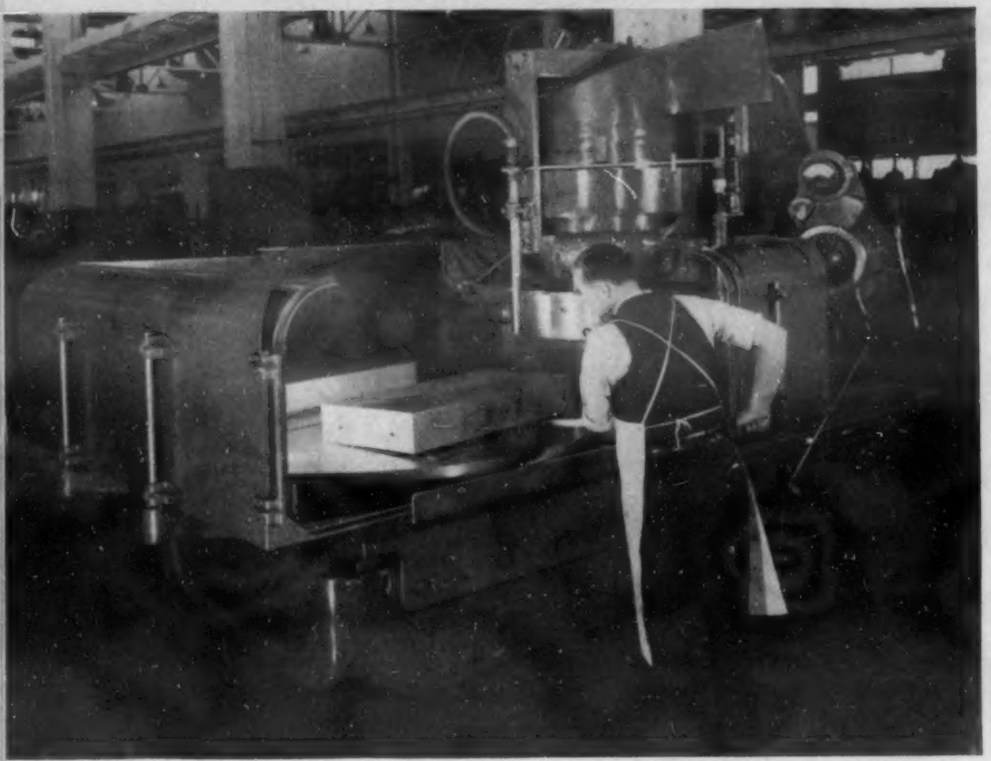
Other Necessary Apparatus

Other apparatus necessary in such a department is as follows:

In the center of this department and just opposite the line of heating furnaces is a row of various sized quenching tanks, holding water, oil or brine. There is also a tank for low temperature oil draw. Some are used for high-speed tools and others for other tools or dies. The temperature of the brine or oil used as quenching media is maintained by a circulating cooling system. The brine is usually kept at about 85 deg. F. and the oil at about 100 to 110 deg. F.

Along the opposite or inner side of the tool hard-

This Blanchard surface grinder swings 84-in.



View showing Ingersoll two-spindle guide pin boring and milling machine and a 14-ft. Ingersoll horizontal-type boring and milling machine.

ening department are, first, in one corner, special sand blasting equipment; nitrate drawing baths suitable for drawing up to 1,000 deg. F.; two electrically heated lead pots, generally for carbon steel parts such as piercing punches and guide pins; and two cyanide furnaces, 32 in. deep for hardening long bars. Further down the line are three straightening presses for bars, broaches, etc., and both Brinell and Rockwell hardness testing apparatus for testing all hardened material.

It may be added that this department is not solely used for tools and dies. In the construction of machinery and for some other purposes, certain castings and other material are heat treated.

The policy of the Ford organization throughout the over 1200-acre plant is good housekeeping—cleanliness and attractiveness with comfort for workmen. All of the furnaces are completely encased in an attractive dark sheet metal—"Wellsville metal"—set off with decorative stainless steel strip covering the edges and joints. Pyrometers for all equipment are housed in this metal panel. As a whole, this department, some 175 ft. long by 42 ft. wide, is a

model in efficiency and attractiveness.

This article would not be complete without a brief description of the tool and die shop as a whole—for the heat-treating department is intimately associated with it.

The Main Tool and Die Shop

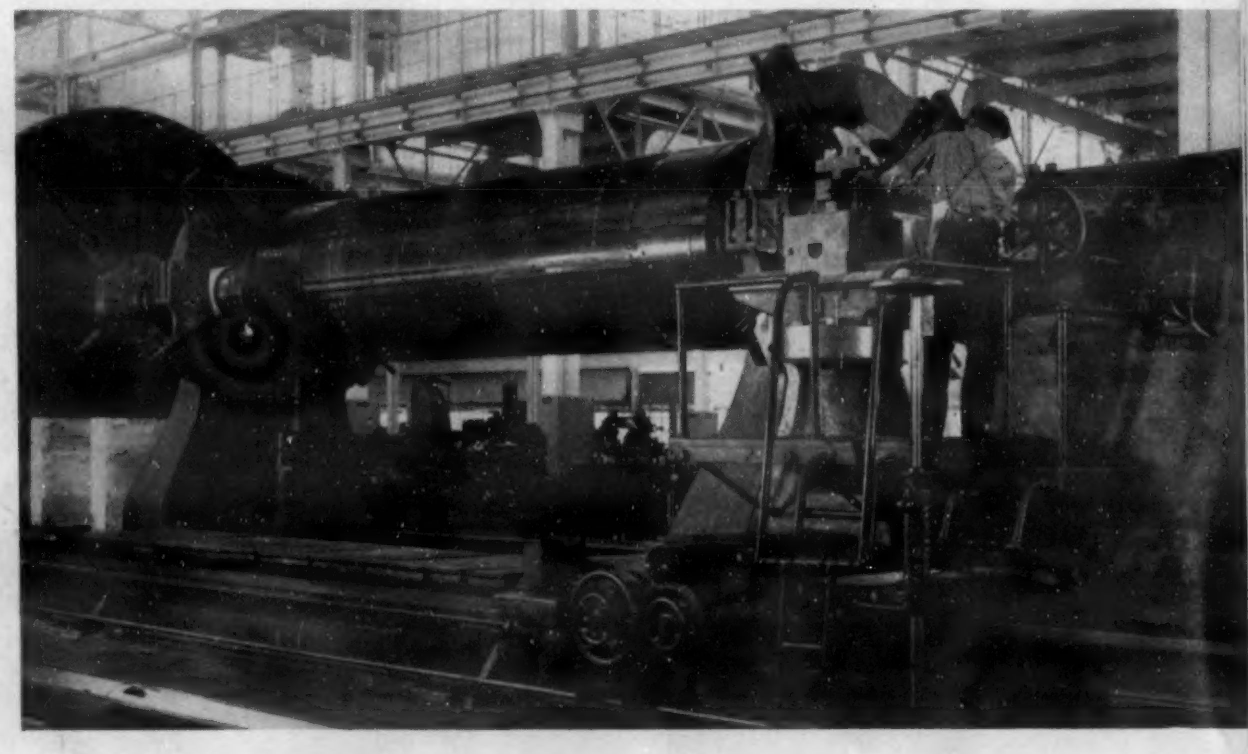
As previously stated, this plant concentrates under one roof the major portion of the tool and die work for the whole plant—exclusive of regular maintenance work. Practically any job of this nature, regardless of size, is done there. The building is 1,225 ft. long and is believed to be the largest in the world designed solely for this purpose. There are about 1,311 machines of all kinds, over 600 of them being new. The plant accommodates about 2,000 men per 8-hr. shift. Many of the machines have been transferred from other locations.

The plant has three main divisions: (1) Body die and small die construction; (2) tool, jig, fixture and gage division; and (3) machine construction and repair division where new machines and general overhauling of plant machinery is taken care of. The entire building is air-conditioned and the lighting and heating leave nothing to be desired.

Massive spotting machines as well as some 17 Keller machines are conspicuous. The color scheme is noticeable as adding to the effectiveness of the lighting arrangements—all overhead steel work and air-conditioning ducts as well as roof and side walls are painted white, the equipment being painted a dark "crane blue" restful to the eye. A feature is the absence of all hand hoists because all lifting is done with electric hoists, traveling hoists and cranes. In this plant dies are constructed, ready for use, weighing up to 80 to 100 tons each.

Of interest to the metallurgist is the use of nickel cast iron for certain large dies having the following composition: C 3.00 to 3.50, Mn 0.60 to 0.80, Si 1.60 to 1.80, S 0.10 max., P 0.18 max., Ni 1.75 to 2.00, and Cr 0.00 to 0.50 per cent. Also of interest is the gradual introduction of flame hardening for certain parts of dies subject to greatest wear. When this is not done, the use of inserts of hard steel in some dies is the common practice—a necessarily expensive and time-consuming operation.

Engine lathe, one of largest in country; 16-ft. swing, 50-ft. centers. Less than a single pound of metal on the coupling of this 57-ton generator rotor was out of true, so the new Ford Tool and Die Shop had a big job making a small repair. The rotor is part of the new 110,000 k.w. turbine generator being installed in the Ford Rouge plant's No. 1 powerhouse. After it was in place, a check-up showed the coupling on the 35-ft. rotor was 1/64th of an inch out of line. So Ford engineers pulled it out, put it on a flat car and hauled it across the plant to this huge lathe in the tool shop. A little metal was taken off here, a little there, and within 4½ hrs. from the time it was centered in the lathe the big rotor was ready to go back to the powerhouse. It was about 1-lb. lighter, but the removal of that 1 lb. was all it took to put it into perfect alignment.



A 10-ft. Cincinnati-Bickford radial drill with half-round table. Four different jobs are set up for work.

A Note on Yttrium-Aluminum Alloys

by W. KROLL

Bel' Airstrasse, Luxemburg

An increase in the high temperature strength, or hot-hardness, of aluminum piston alloys, could it be obtained without impairment of the other properties required, would be advantageous. One might hope that the rare earth metals would alloy with aluminum, possibly forming solid solutions, but experience with the cheaper metals of the series has not been very promising.

Cerium is the cheapest one, and is included in some aluminum alloys(1). Barth(2), Meissner(3, 4) and the writer(5) have discussed the effects of cerium. It is claimed that cerium can neutralize the effects of iron. One Ce-containing alloy, called ceralumin is said to be in some commercial use in England.

Lanthanum-aluminum alloys have been studied by Canneri(6) but their properties are not promising. Neither Ce nor La appear likely to be useful from the point of view of high temperature strength.

From the melting points, as given by Trombe(7) it would appear that yttrium might be of benefit. These follow:

Element	*Deg. C.*
Cerium	815
Yttrium	1490
Lanthanum	812
Neodymium	840
Praseodymium	932
Samarium	1350

Fig. 1—Aluminum-yttrium alloy with 16.35 per cent Y. Etched with 1:100 hydrofluoric acid. 270 X.

While the last three elements above would be extremely expensive, yttria, Y_2O_3, of 98 per cent purity is available at a price of say $30 to $35 per lb. of contained yttrium.

One might reduce Y into Al by adding the oxide to a cell in which Al was being reduced, or, possibly, by dissolving the Y_2O_3 in cryolite and reducing with Al. An attempt in which 810 g. cryolite was melted in an Acheson graphite crucible, heated to 1100 deg. C., 83 g. Al added, and 100 g. Y_2O_3 stirred in with a graphite rod, resulted in an alloy containing only 1 per cent Y.

The oxide was converted to fluoride and another attempt made by melting 130 g. YF_3 and 35 g. NaF in the crucible and adding 80 g. Al at 1100 deg. This gave an alloy containing 3 per cent Y. In a third attempt 130 g. YF_3 and 35 g. NaF were melted, 72 g. Al added, then 14.5 g. distilled Ca added and stirred in a little at a time. The reaction at 1100 deg. C. was very violent.

The product recovered weighed 75 g., contained 16.35 per cent Y, and was free from Ca. This rich alloy was then used in making up small melts of a few Al alloys. The structure of the rich alloy is shown in Fig. 1. The Al matrix contains pale violet dendrites readily etched by HF. They appear to represent a compound. The alloy was soft, fine grained, white and entirely stable in air. As the Table shows, the rich alloy was only slightly harder than the commercial aluminum at any of the test temperatures.

High Cu and high Si alloys, representing two classes of simple piston alloys, were made up with and without about 8 per cent Y. The melts were made in alumina crucibles under argon, poured in air into an iron mold. Hardness determinations were made on the alloys as cast.

TABLE

Alloy No.	Composition, Per cent			Brinell-Hardness at			
	Y	Cu	Si	Room temperature	100° C.	200° C.	300° C.
1	7.95	12.60	...	96	74	57	38
2	...	12.60	...	86	83	69	35
3	7.72	....	23.4	86	69	55	33
4	...	....	23.4	65	57	41	25
5	16.35	....	...	33	31	27	21.8
6	Commercial Aluminum *			28	27	23.8	17.2

* Contained 0.6% Si, 0.4% Fe. This Al was used in the reduction experiments and as base for the other alloys.

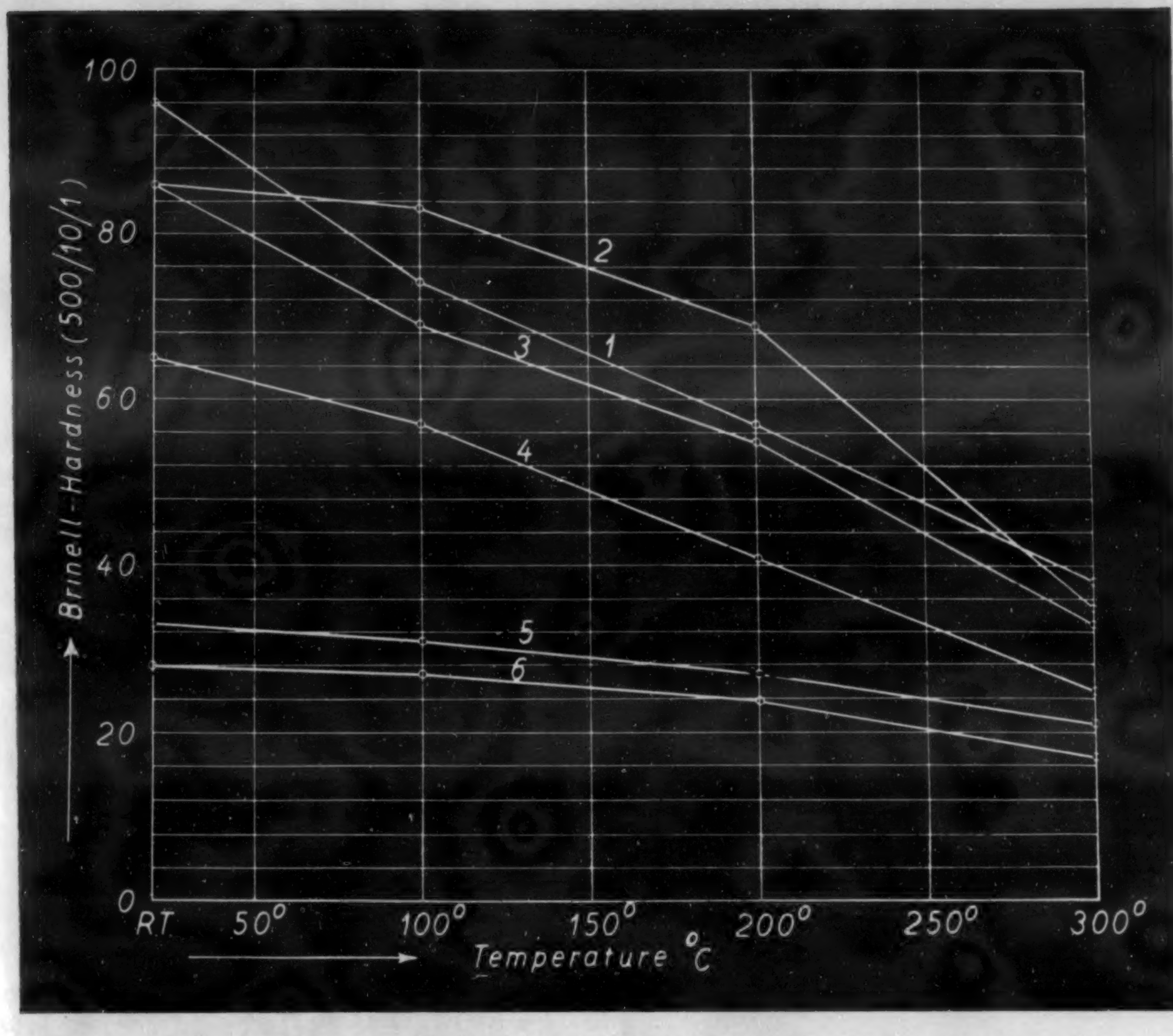


Fig. 2.—Hot-hardness of Y-Al alloys in comparison with ordinary Al and Y-free alloys.

While the Y additions somewhat increased the hardness and maintained a slightly higher level of hardness over the temperature range to 300 deg. C., the effect shown in the Table and Fig. 2 is not impressive.

According to Steudel and Sterner-Rainer,[8] commercial piston alloys run between 23 and 38 Brinell at 300 deg. C.

Since the recovery of Y by Ca reduction was only 16 per cent, the cost of the Y in metallic form is around $250 per lb. Presumably this figure could be materially reduced by starting with yttrium fluoride and electrolytically reducing the metal into a molten aluminum cathode.

Because of the cost of yttrium and the minor effect it produced in these tests the alloys have not been studied further. The 16.35 per cent Y alloy could be rolled, and, were the element cheaper, a study of the properties of cast and wrought alloys, including their precipitation hardening possibilities, would be of interest. The indications are that yttrium would be an entirely compatible alloying element for aluminum, and it would be odd indeed if no alloy could be found in which its effect would be beneficial. Indeed, since cerium acts as a hardener in magnesium, one might expect that yttrium also might be utilized in magnesium alloys.

But, at the price, the effect must needs be most outstanding to justify commercial use.

Bibliography

1 Murphy, A. J. *The Metal Industry*, London, 1935, Vol. 47, page 346-47.

2 Barth, O. *Metallurgie*, 1912, Vol. 8, page 270-276.

3 Meissner, K. L. *Metall und Erz*, 1924, Vol. 21, page 41-44.

4 Meissner, K. L. *Metall und Erz*, 1925, Vol. 22, page 247 and Patent application G.57125/4ob of July 20, 1922.

5 Kroll, W. *Metall und Erz*, 1926, Vol. 23, page 226-227.

6 Canneri, G. *Metallurgia Italiana*, 1932, Vol. 24, No. 2 and *Alluminio*, Vol. 11, 1933, page 87.

7 Trombe, F., *La Technique Moderne*, 1938, Vol. 30, page 855.

8 Steudel, H. and Sterner-Rainer, R. Werkstoffhandbuch Nichteisenmetalle, 1927, Div. J 9, page 2.

9 Gmelin and Kraut. Handbuch der anorganischen Chemie, Vol. VI, Division 2, 1932.

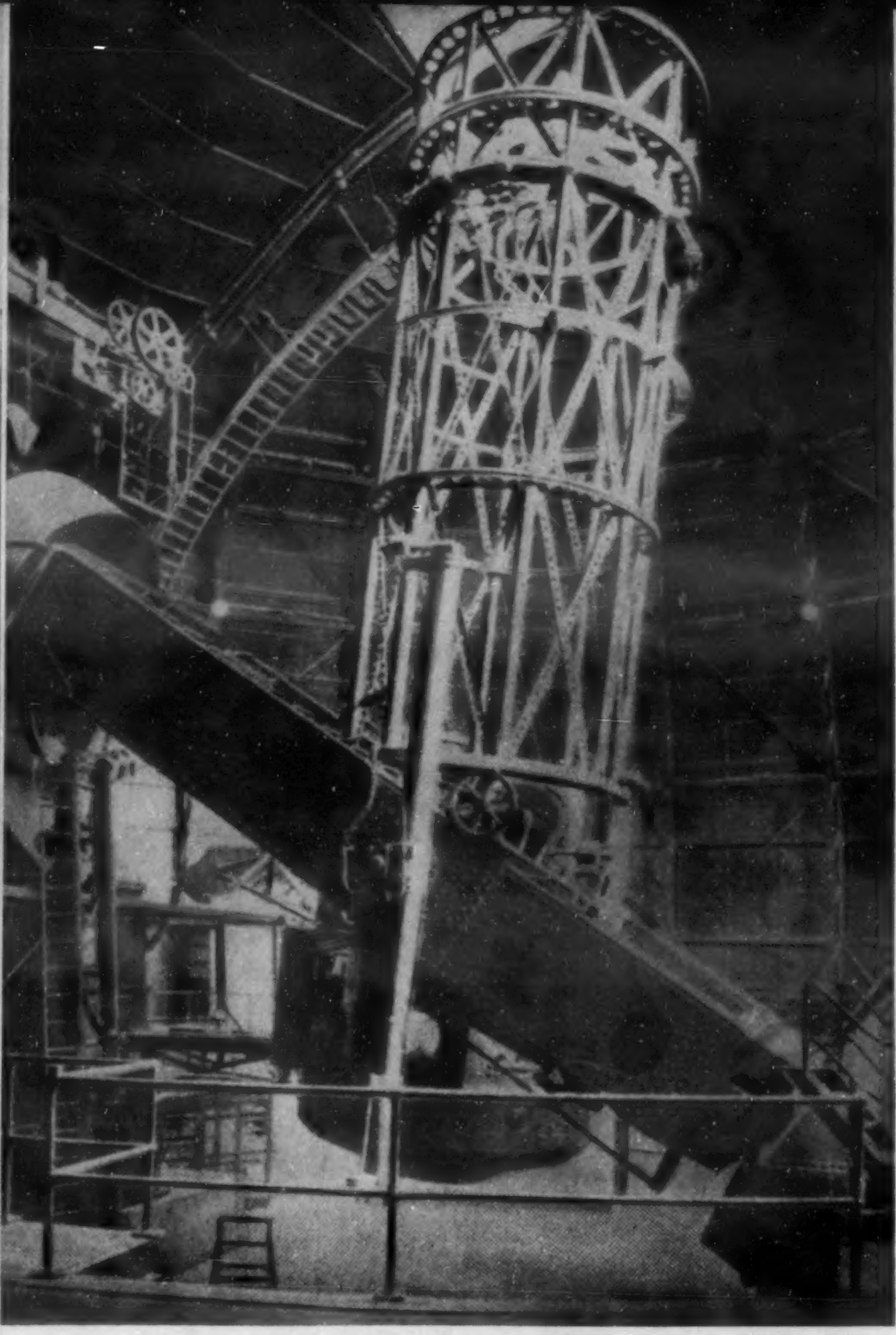


Fig. 1. The 100-in. telescope at Mt. Wilson Observatory

Mounting of the 200-Inch Telescope

•

A Welded Structure

by Frank Fredericks and N. L. Mochel

Resident Engineer for California Institute of Technology, and Metallurgical Engineer Respectively, Westinghouse Electric & Mfg. Co., South Philadelphia Works, Lester, Pa.

This paper, written in 1938, is one of a large number which were submitted for awards in the "award program in 1938 sponsored by the James F. Lincoln Arc Welding Foundation, Cleveland, which showed savings of $1,600,000 available to industry through wider application of arc welding." The authors of this paper received award No. 1254 of $101.75 in the structural, miscellaneous classification. The paper is a description of the general design considerations, materials, general welding considerations, stress relieving, fabrication and welding problems involved in the construction of the mounting of the world's largest telescope.

—The Editors.

THE 200-IN. TELESCOPE MOUNTING, nearing completion at the South Philadelphia Works of the Westinghouse Electric & Mfg. Co., for the California Institute of Technology, and to be erected on Mount Palomar, Cal., is an outstanding example of the application of the latest developments in the art of welding.

This telescope owes its inception to the genius of the late Dr. George Ellery Hale of Yerkes and Mount Wilson fame, and its realization to funds furnished by the Rockefeller Foundation. So much has appeared in the popular and technical press over the past several years, dealing with the history and early development of this project, especially of the

mirror, that it is unnecessary for the purpose of this article to deal with such matters.

The marked increase in size of this telescope, over any previously built or now under construction, should be appreciated. Refracting telescopes have been built since 1608, and reflecting telescopes since about 1663. The largest refracting telescope ever built is the 40-in. one at Yerkes Observatory in Wisconsin, built in 1897. The size of reflecting telescopes increased from the original 2-in. of Newton in 1671 to a 72-in. built by Lord Rosse in Ireland in 1832. This is no longer in use. The following list shows the seven largest reflecting telescopes in use today; and the 200-in., 82-in. and 73-in., now under completion, are listed in the positions they will occupy when placed in service.

Position	*Dia. In.*	*Location*	*Year*
	200	Mt. Palomar, Calif.	1940
1	100	Mt. Wilson Observatory, Calif. ..	1917
	82	McDonald Observatory, Texas ..	1938
2	74	Dunlop Observatory, Canada	1935
	73	Radcliffe Observatory, So. Africa	1938
3	72	Dominion Observatory, Canada ..	1919
4	69	Perkins Observatory, Ohio	1932
5	61	Harvard Observatory, Mass.	1934
6	60	Harvard Observatory, So. Africa .	1933
7	60	Mt. Wilson Observatory, Calif. ..	1908

Thus the 200-in. telescope for Mt. Palomar has a mirror twice the diameter of that of the largest telescope ever built previously. The mounting for the 200-in. telescope will weigh approximately eight times as much as the 100-in. at Mount Wilson; it will collect four times as much light, widen the volume of space that may be observed eight times, and permit the observers to go twice as far into space as has been heretofore possible. These few figures emphasize the enormous advance in size and weight that has been made in a single step, and the importance of the project to the broad field of science.

Description and General Design

The present largest telescope, the 100-in. instrument of the Mount Wilson Observatory, is of the so-called yoke type. This is shown in Fig. 1. It was completed during the World War, without any radical departures from the accepted structural methods of the period. The telescope tube is mounted on the so-called declination axis in the yoke so that it can swing in the meridian from North to South. The yoke is in the form of a closed frame of riveted construction, carried by mercury flotation, in conjunction with roller bearings which merely serve to locate and define the polar axis about which the yoke may be rotated from East to West.

This design has the serious disadvantage that the tube cannot be brought down to the Southern horizon, nor can it reach within an appreciable angle of the celestial pole, owing to the closed frame of the yoke.

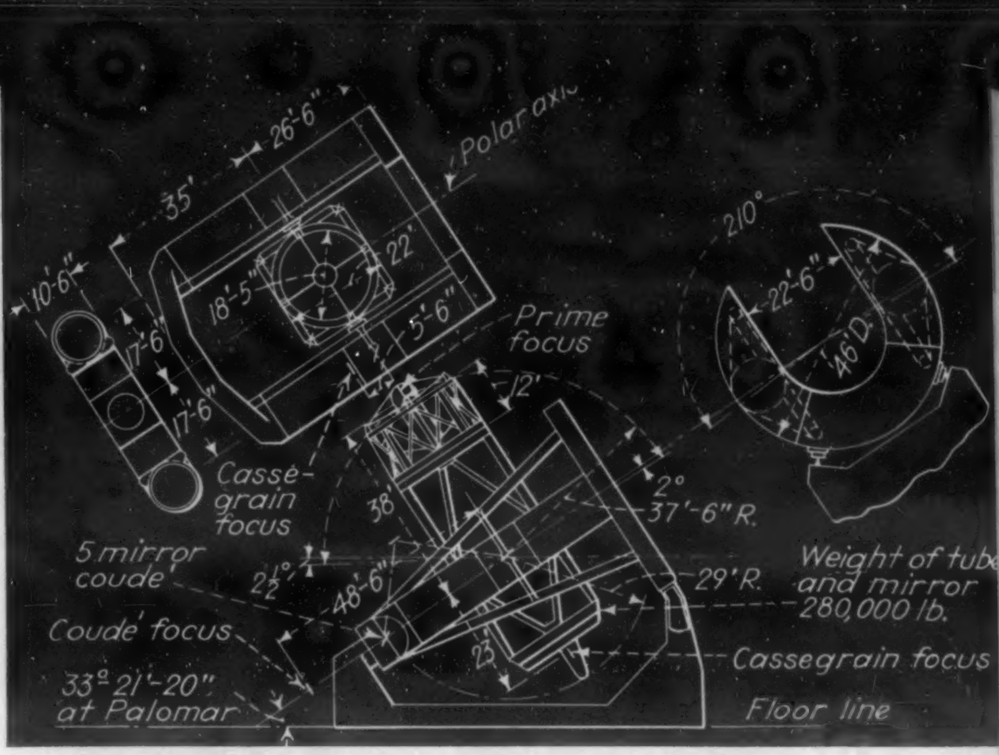


Fig. 2. Diagram of the 200-in. telescope.

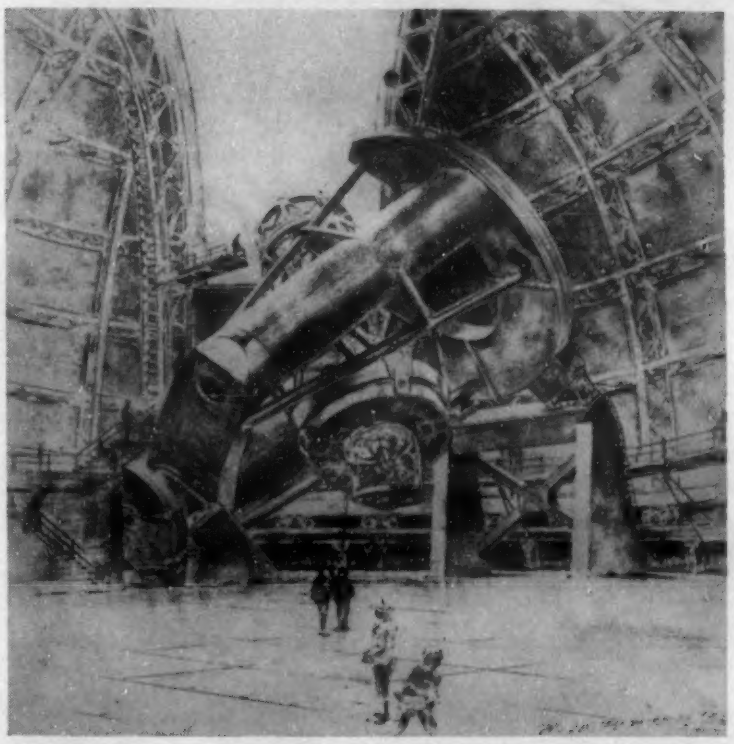
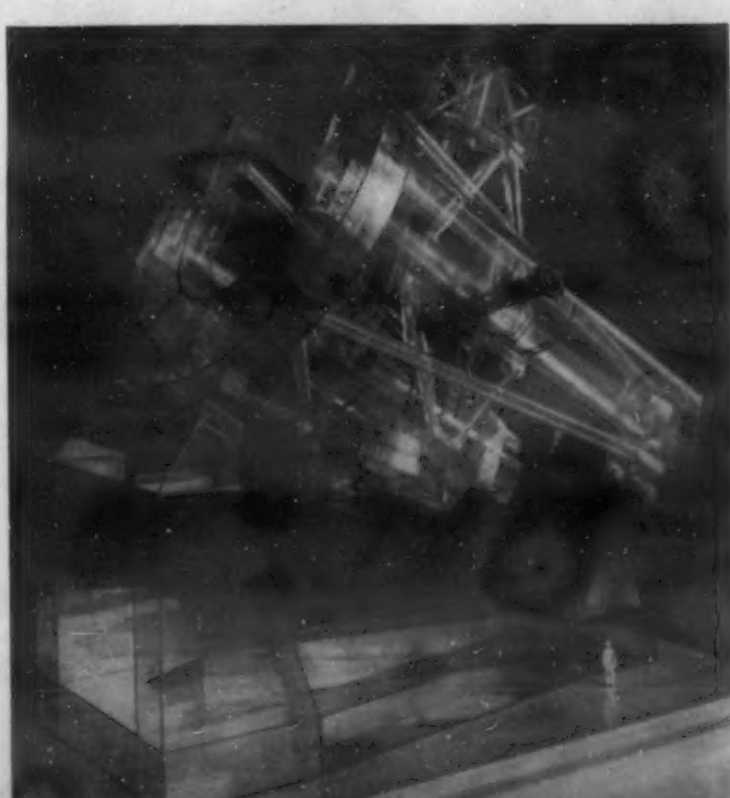


Fig. 3. Artist's conception of the 200-in. telescope.

Fig. 4. 1/32 scale celluloid model of 200-in. telescope.



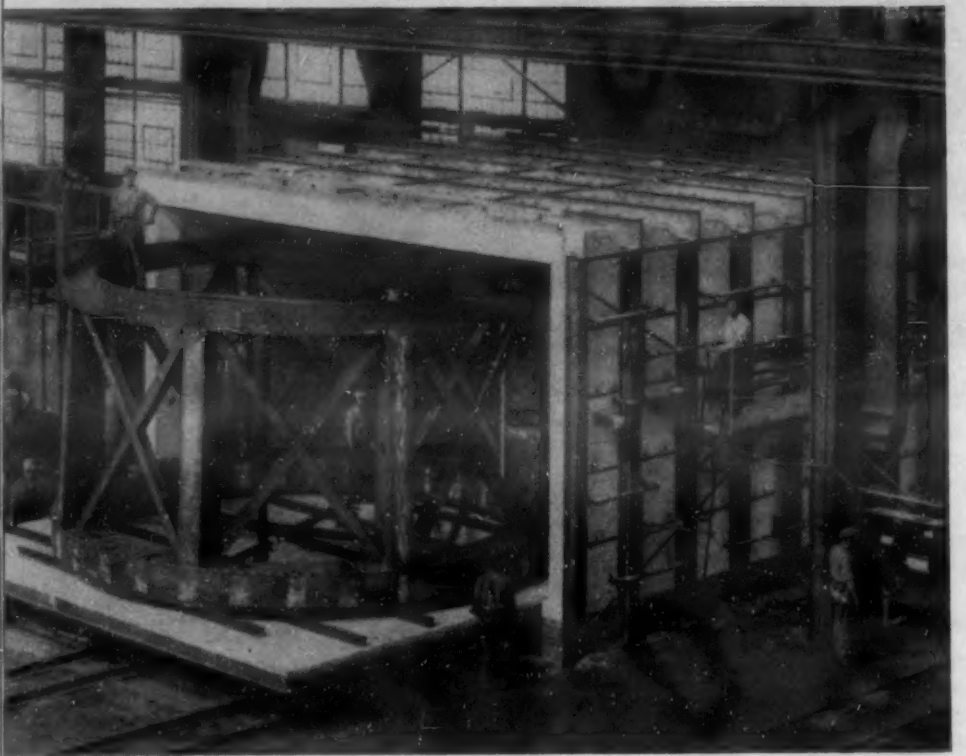


Fig. 5. Prime focus cage on car of annealing furnace.

The same general type was adopted for the mounting of the 200-in. telescope. A fundamental feature of the design was its ability to reach from $2\frac{1}{2}$ deg. above the Southern horizon to 2 deg. below the north celestial pole. This requirement led to the enlargement of the north polar bearing to a journal 46 ft. in diameter, slotted out in the form of a horseshoe.

Preliminary designs were first made of an openwork structural truss type of yoke, comprising a horseshoe girder of riveted construction, the connections of the individual members to be riveted in the field. Investigation of the deflection of a yoke of this design showed that a more rigid and heavier structure was desirable, in order to reduce to a minimum the displacements of the optical axis during rotation from East to West. This was particularly true of the horseshoe or north bearing journal.

These requirements led to the necessity of such heavy plates for the horseshoe, with closely spaced stiffening diaphragms, that riveted construction seemed out of the question.

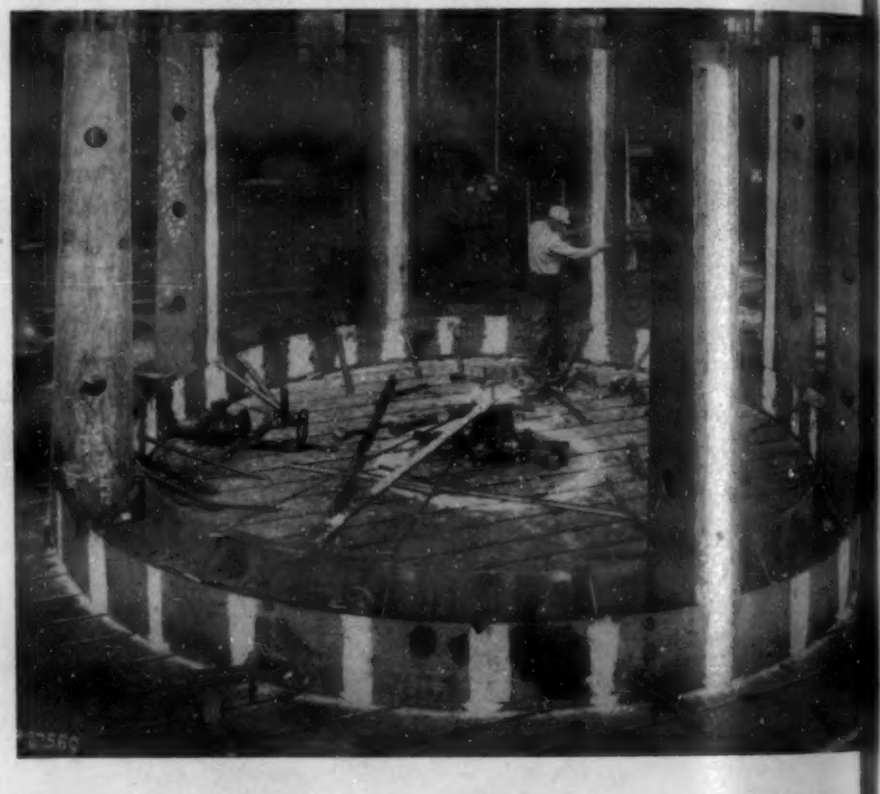
The state of the welding art was now known to have arrived at a stage where a thoroughly reliable welded structure could be ensured by using the best methods and equipment available. Good examples of heavy welding were to be seen in such structures as the penstocks and cylinder gates built for Boulder Dam.

The final design, therefore, visualized a completely welded structure, subdivided into units whose size was limited by the largest machine tools available, and by transportation to and from tidewater. These units or sections are provided with machined joint faces or connections, and will be bolted and doweled together on erection. No field welding is contemplated in any of the main members, as the introduction of shrinkage stresses is highly undesirable.

The general requirement in the design of the telescope mounting was that the members should be as stiff and rigid as possible, consistent with a minimum of weight. Units of box type section were therefore generally employed.

On account of the stiffness requirement, the stresses are on the whole quite low. An ample margin of strength therefore exists in all welded joints. For this reason it was not thought necessary to radiograph the welds, their character being known from similar work which had been tested in that way.

Fig. 6. Fabrication of prime focus cage.



A general diagram of the mounting is shown in Fig. 2, and an artist's conception in Fig. 3. The yoke is formed by the horseshoe at the north end, a cross member at the south end, and tubular yoke sections joining them. The declination axis of the tube is carried on ball bearings in the center sections. The north polar bearing consists of equalized bearing shoes carrying the horseshoe on a film of oil established by a positive pressure pump. The south bearing is in the form of a 7-ft. spherical journal carried on three self-aligning shoes, each carrying a load of 160 tons on a film of oil.

The tube itself is a very simple structure consisting of four central panels in the form of a square,

with diagonal struts joining its corners to a top and a bottom ring. At the top of the telescope tube, enclosing the "principal", "primary", or "prime" focus of the reflecting mirror, is an openwork structure known as the prime focus cage, having suspended within it an observer's house. This is the first time in any telescope that space could be given to such an object in the direct path of the light to the mirror, without an excessive percentage of loss of area. In the 200-in. telescope this amounts to about 12 per cent of the area of the mirror and is less than the loss in a corresponding Newtonian telescope.

Fig. 4 shows a 1/32 scale model, constructed of celluloid, closely approximating the final design. At several stages during the design deliberation, use was made of such celluloid models of the various parts for deflection studies. It is interesting to note that in gluing together the member parts of such models, shrinkage stresses and distortions take place that are not unlike those experienced in actual welding.

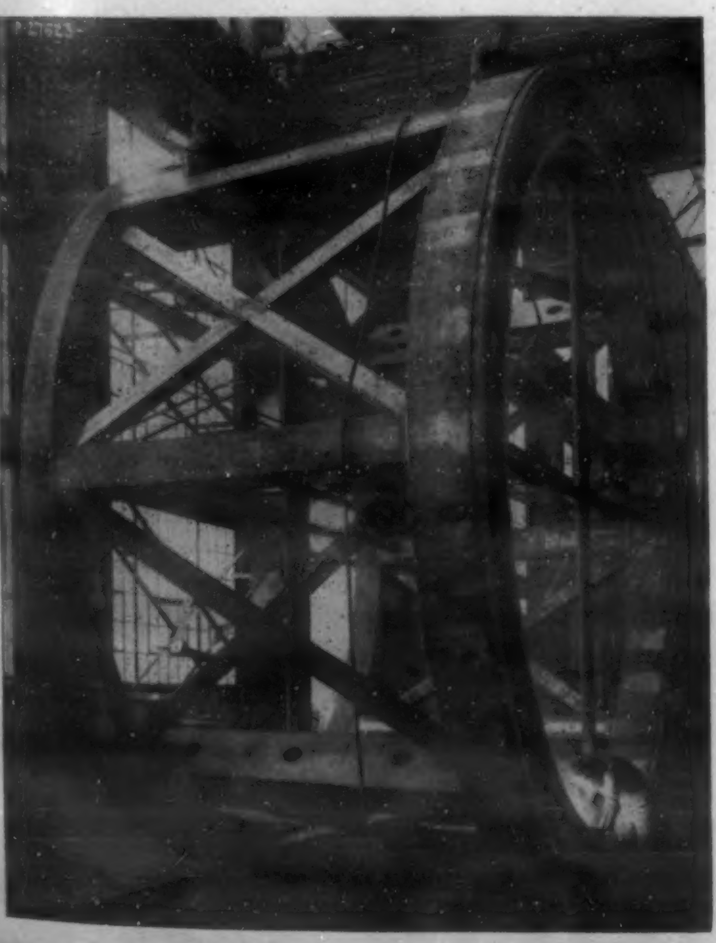
Materials

In any discussion of welding, one is naturally interested in the materials that are to be used, and that must submit to welding. There has been an erroneous impression that a telescope must be constructed largely of special alloys that have low expansivity. While it is true that some materials of this nature are used in connection with the mirror and other optical parts, the great bulk of material used for the tube and mounting is quite ordinary mild carbon steel. All of the materials that have been welded are of known commercial grades, being regularly welded by the manufacturer.

In all cases, plates, bars, and structural shapes have been rolled by one supplier from selected and approved heats, to give the greatest possible uniformity of composition. Plates less than 1½ in. thick were made of rimming steel of flange quality. All such steel for the tube was made from a single heat, specially melted for the purpose. Plates 1½ in. thick and greater were rolled from silicon-killed steel poured into hot-top ingots, to guarantee soundness of section.

Two carbon-molybdenum steel forgings were used in building up the declination bearing housings. Hammer-welded pipe was used for the bracing pipes from the horseshoe to the south cross-member. Carbon steel forgings were used for the box girder barrel and the torque tube, and carbon steel castings for the main parts of the spherical bearing. There are of course many parts that are not joined by welding, and these are made of various materials suitable for the purpose. The analyses of the materials actually welded are given in the table.

Fig. 7. Final welding of prime focus cage.



General Welding Considerations

Arc welding only has been employed, and in all cases heavily coated electrodes were used. It is well known today that electrodes can be devised that will best meet some given condition of deposition. Full advantage of this has been taken, and three kinds of electrodes, as regards position of deposition, have been used. One was used for all down-hand butt-welds; another for all down-hand or horizontal fillet welds; and still another for welds that of necessity had to be made in a vertical position. Overhand welding was avoided entirely.

Fig. 8. Fabrication of top ring of tube.

TABLE OF ANALYSIS OF MATERIALS JOINED BY WELDING

Part	Material	C	Mn	P	S	Si	Mo
Tube and Cage	Plate	0.10	0.40	0.016	0.034	0.16	
	Heavy Plate	0.24	0.50	0.009	0.023	0.25	
	Shapes	0.10	0.40	0.011	0.036	0.12	
	Bars	0.09	0.39	0.016	0.025	0.18	
	Bars	0.12	0.40	0.010	0.030	0.04	
	Bars	0.09	0.38	0.016	0.030	0.05	
	Bars	0.09	0.40	0.016	0.035	0.05	
	Bars	0.09	0.40	0.016	0.043	0.03	
	Bars	0.16	0.45	0.015	0.036	0.08	
Horseshoe	Plate	0.12	0.42	0.011	0.028	0.16	
	Plate	0.12	0.42	0.013	0.023	0.16	
	Heavy Plate	0.22	0.50	0.031	0.028	0.22	
	Heavy Plate	0.24	0.44	0.016	0.027	0.19	
	Heavy Plate	0.24	0.53	0.014	0.029	0.25	
	Heavy Plate	0.23	0.49	0.015	0.029	0.23	
Bearing housing	Heavy Plate	0.23	0.56	0.015	0.032	0.26	
	Forged Rings	0.18	0.64	0.022	0.024	0.34	.54
Tubular yoke Sections & south cross-member	Plate	0.12	0.32	0.016	0.020	0.16	
	Plate	0.10	0.43	0.013	0.025	0.16	
	Plate	0.12	0.42	0.011	0.028	0.16	
	Plate	0.12	0.42	0.013	0.023	0.16	
	Heavy Plate	0.24	0.47	0.018	0.023	0.27	
	Heavy Plate	0.25	0.48	0.011	0.022	0.27	
	Heavy Plate	0.27	0.54	0.015	0.027	0.26	
Brace pipes	H-W Pipe	0.18	0.42	0.012	0.038		
Box girder barrel	Forging	0.23	0.63	0.016	0.025	0.17	
Torque tube	Forging	0.23	0.63	0.016	0.025	0.17	
Spherical bearing	Castings	0.28	0.71	0.029	0.038	0.34	
		0.27	0.77	0.025	0.030	0.35	

The electrodes used were of such nature that they behave equally well with either D.C. or A.C. welding apparatus. Both D.C. and A.C. units were used during the work. The A.C. welding was found to be especially useful for welding into corners and where "hot" welding was desired as in heavy sections.

Welders employed in the manufacturer's plant are called upon to qualify under several codes and specifications. For example, it is not unusual to have welded construction under way at the same time requiring conformance to the A.S.M.E. Boiler Code for Unfired Pressure Vessels, the A.P.I.-A.S.M.E. Code for Unfired Pressure Vessels for the Petroleum Industries, the U. S. Navy specifications, the American Bureau of Shipping, the Pressure Piping Code, the specifications of several well-known insurance companies, and the Bureau of Marine Inspection and Navigation. Of necessity, the manufacturer has developed all-inclusive codes and process specifications of his own, so that qualifications under his own more extensive requirements qualify an operator to perform under any of the above codes and specifications. The operators performing welding on the telescope mounting were qualified under this system, and were welders of the highest type.

In general, manual welding has been employed, excepting the tubular yoke sections and bearing housings, which were welded with the automatic welder, and these will be referred to later.

In welding such large parts as those to be described, careful study and planning of the work are very important. There is a best place to start, and a best sequence of operations. One does not have an opportunity to practice with a first few and in this way develop a final technique. There are no trial pieces to be thrown away. In the case of some parts, there was but one piece of a kind to make; in some cases there were two like pieces.

Fig. 9. East or west tube panel.

For welding such large structures as those under discussion, large leveled floor plates are of absolute necessity. The need for ample space, for proper supporting, and of firm foundation will be apparent from an examination of a number of the illustrations accompanying this article.

The welding art has certain advantages over other methods of fabrication when it comes to supporting and clamping down; as clamping blocks, struts, stays, etc., can be attached just where wanted, by welding, and readily removed later. The use of this feature of the art will be observed in a number of the illustrations.

Stress Relieving by Annealing

It has been the aim to produce a telescope which will be a good and serviceable instrument a hundred years from now, and in which no material distortion due to aging or the release of stresses shall take place. It was therefore considered of prime importance that every fabricated welded piece should receive a thorough annealing. Several of the main pieces were therefore annealed twice, even three times, between and after successive welding operations.

It is standard recognized practice to stress-relieve welded mild carbon steel structures by heating slowly in a suitably constructed furnace to a temperature of 1100 to 1200 deg. F., holding for a period of time proportioned on the basis of at least 1 hr. per in. of thickness and then cooling under controlled conditions.

In order to further assure the thorough stress-relief of the telescope parts, a double annealing cycle has been used in all cases. The parts were

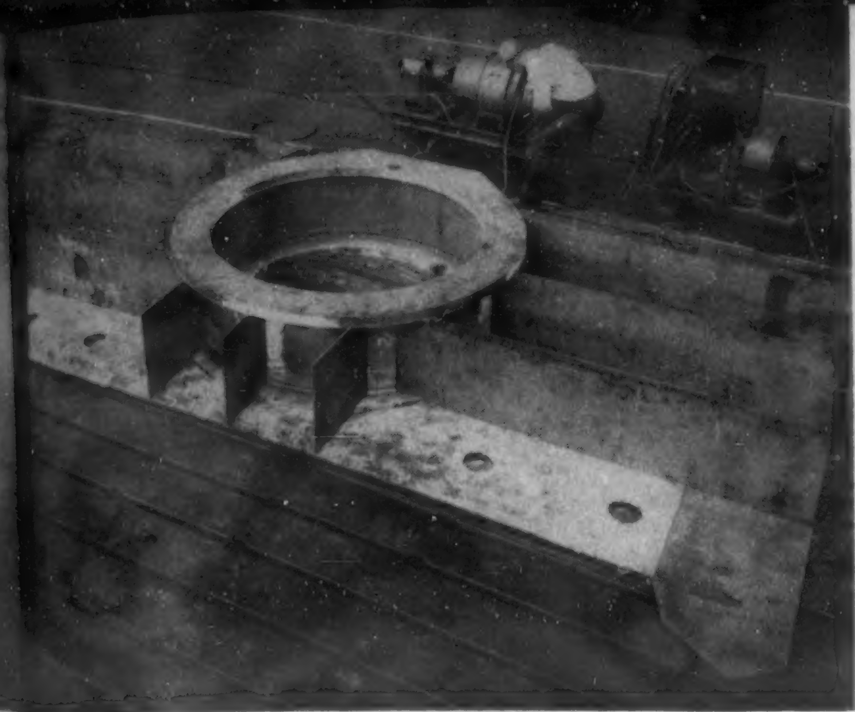


Fig. 10. Fabrication of east and west tube panels.

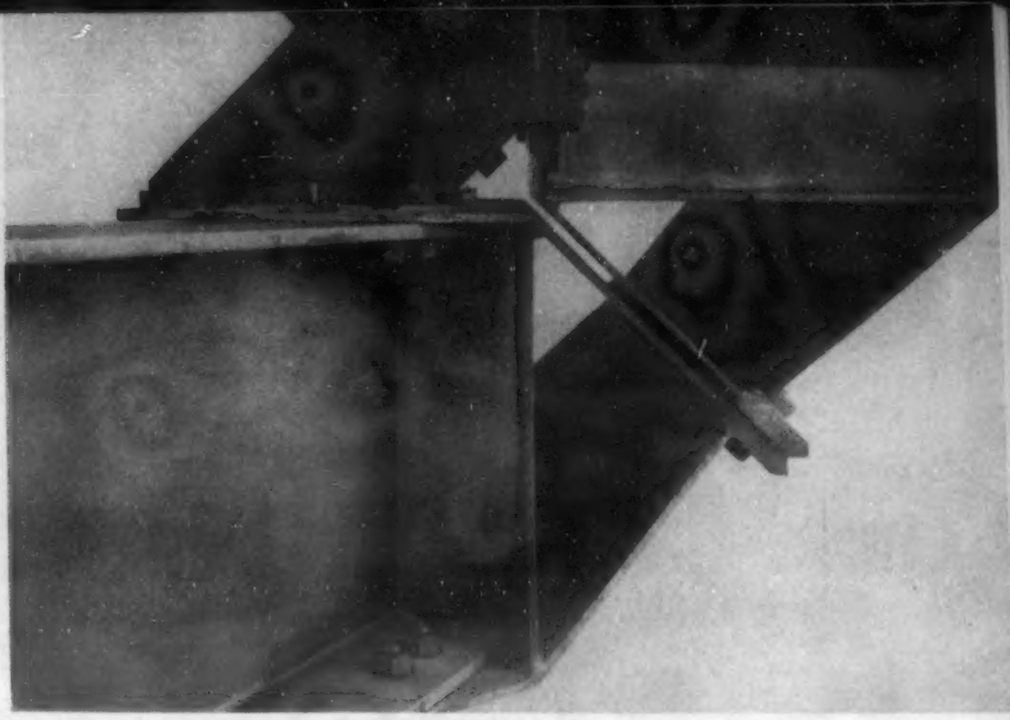


Fig. 11. Corner flanges of tube panels.

heated slowly to 1150 to 1200 deg. F., held for a period of 3 hrs. for the first 1 in. of thickness, plus an additional hour for each additional 1 in. of thickness or fraction thereof, followed by slow cooling in the furnace until the temperature had fallen below 600 deg. F., and then repeating this cycle in its entirety and cooling below 300 deg. F. before the furnace doors were opened.

Annealing Furnace

A 24-ft. by 24-ft. by 14 ft. annealing furnace was therefore specially built for the telescope, to accommodate all but the longest single piece. This furnace was built lightly, for temporary use only, to stand about 12 to 15 annealing operations. To date it has already stood 30 anneals, and is expected to do duty for at least 8 more operations on worm gear castings for the telescope. This furnace is shown in Fig. 5, with the prime focus cage being moved into position. The work rested on a car bottom for ease of handling. A special type of gas burner was used that gives a quiet acting flame and avoids long hot flames impinging upon the work. Burners were also located in the truck or car at the front of the furnace to avoid a "cold spot" at that position.

The door or front cover of the furnace is made in sections that hang from the roof and tightly seal the furnace. Baffles of heat insulating bricks were built up at four points where the outside diameter of the cage, or other parts, came too close to the walls and the burners, to prevent undue heating or overheating at these points. Thermocouples were placed in actual contact with the work, and continuous autographic records were made from at least four positions throughout all annealing periods.

Heat-Treating Cycle

The following summarizes the treatment of the prime focus cage, as an example:

12 hrs. heating to 1160 deg. F.
6 hrs. holding at 1150-1160 deg. F.
11 hrs. cooling to 600 deg. F.
10 hrs. reheating to 1150 deg. F.
6½ hrs. holding at 1150-1160 deg. F.
42 hrs. cooling to 125 deg. F.

Care was taken at all times to properly support the work during annealing. In Fig. 7, showing the prime focus cage, it will be observed that crossed braces made of 4-in. double extra heavy pipe were welded into place at both ends, to securely hold the rings in shape during handling and annealing. If one closely examines Fig. 5, it will be noted that additional tubular members were placed in an upright position between the crossed members to prevent their sagging and possibly distorting the ring sections during annealing. Also blocks were placed on the floor underneath the lower crossed members to prevent their sagging. Supporting of bracing is just one item of the care that was used in the work.

Description of Work, Welding Problems, Etc.

The prime focus cage is bolted to the top of the

Fig. 12. Assembled tube-view from crane—south side uppermost.

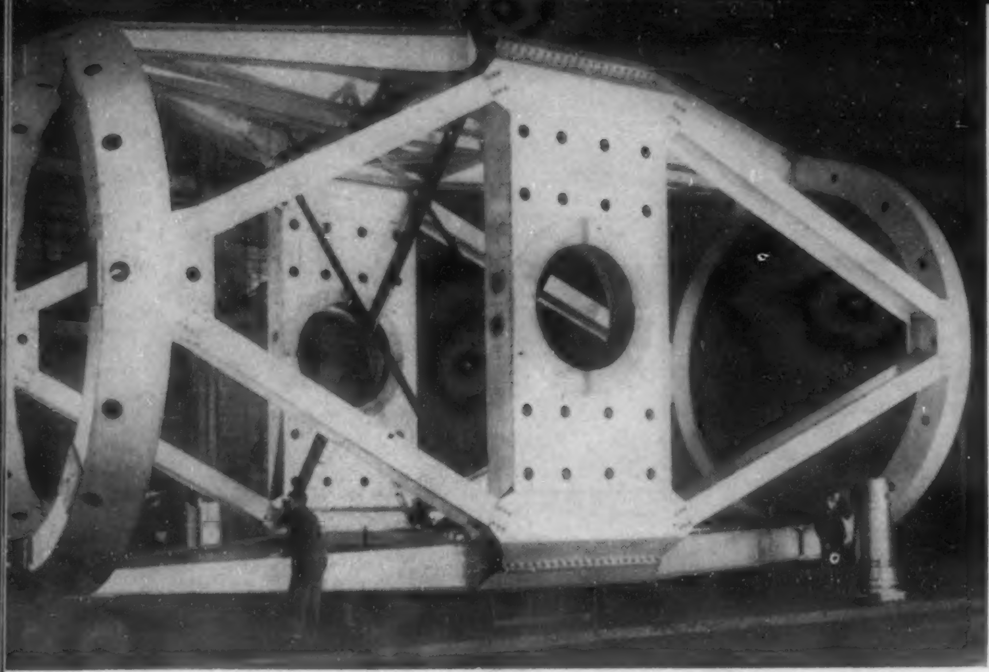


Fig. 13. Assembled tube-view from west side.

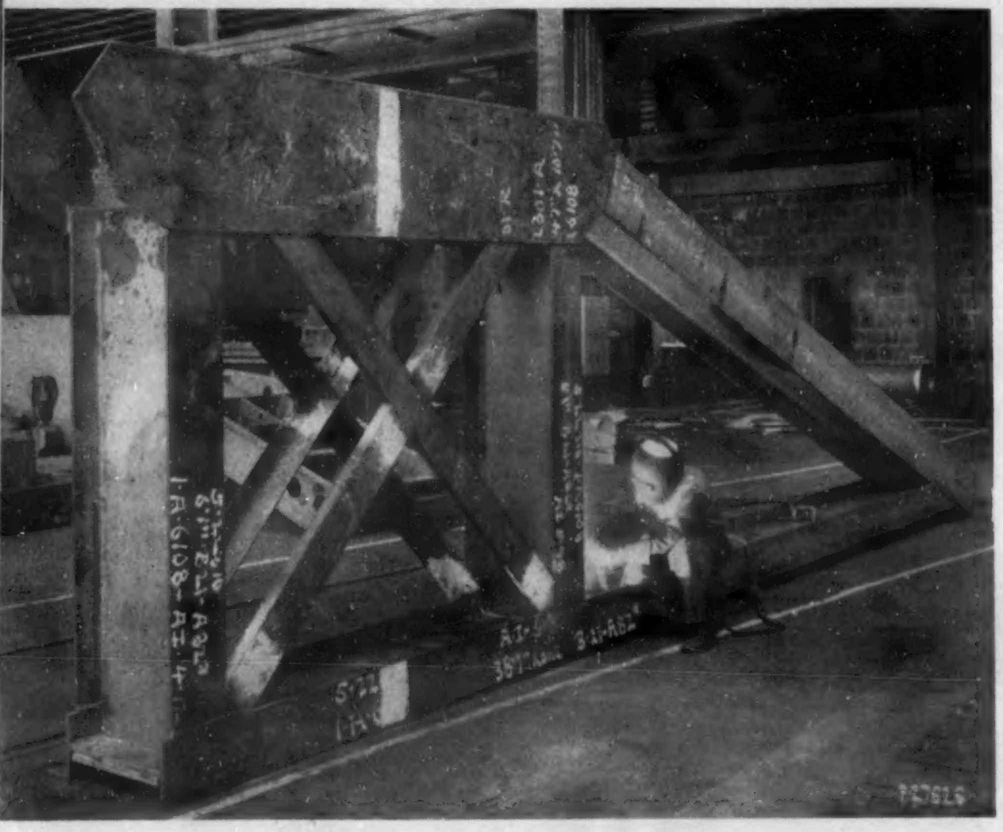


Fig. 14. South panel truss.

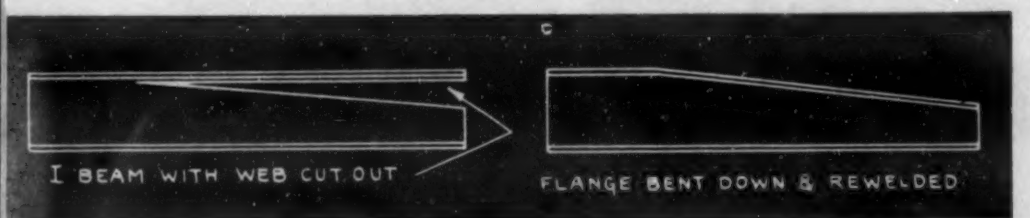


Fig. 15. Tapered I beam for south panel.

telescope tube and contains the observer's house with its optical equipment. It is a one-piece welded structure 22 ft. in diameter and 12 ft. high weighing 23,200 lbs. when machined. It consists of a bottom ring of box construction joined to a top ring of I section by eight box section columns and cross braced with 6-in. H beams. It has a very high bulk to weight ratio.

Fig. 6 shows the commencement of fabrication of this piece and illustrates the general method of working to a layout scribed on the floor plates, using clamps, bracing, and jacks when necessary to make the material conform to the desired alignment. An interesting feature of this assembly is the use of a spacing fixture or jig for accurately locating 40 3-in. pipes forming pockets for nuts having a radial clearance of only $\frac{1}{2}$ in. around them. Actually there was only $\frac{1}{4}$ in. clearance between the inside of the pipes and the spot facing cutter used for making a seat for the nuts. This spacing fixture is seen in the foreground.

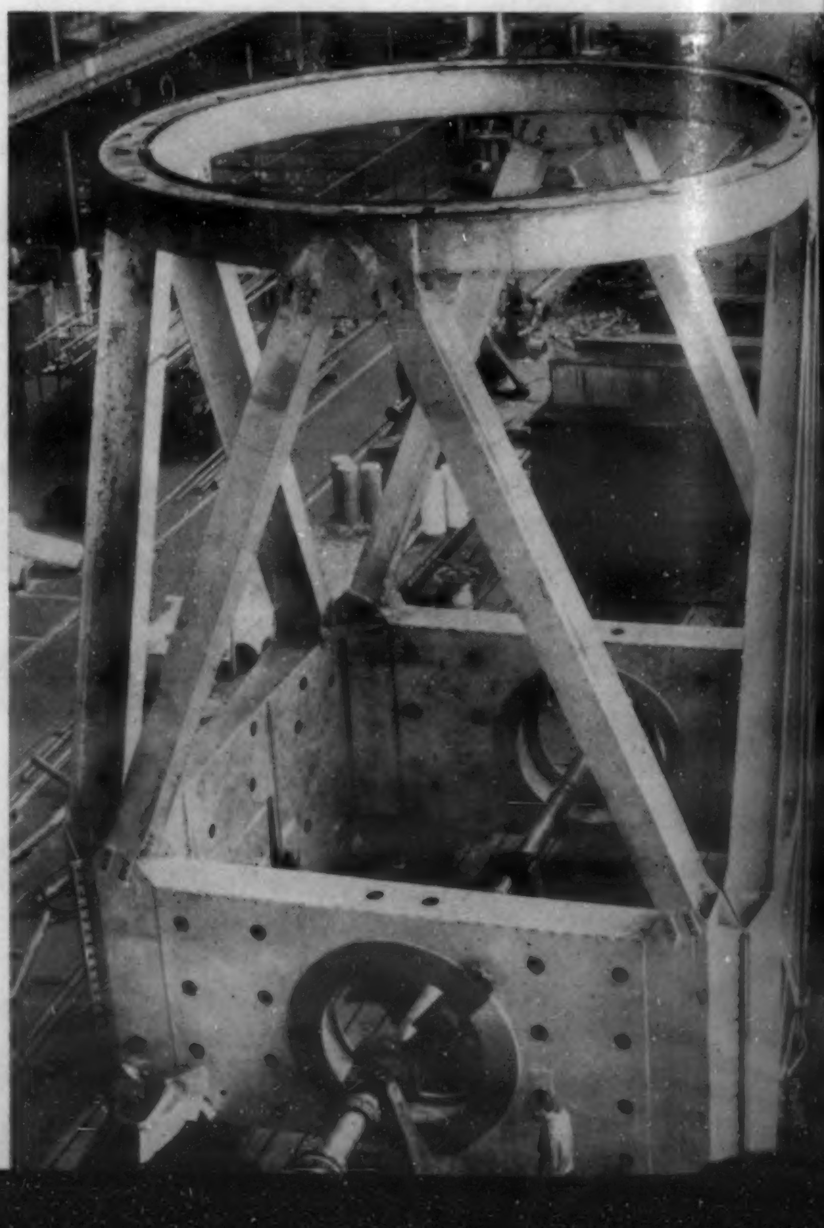
The vertical columns in this piece are composed of $\frac{1}{2}$-in. and $\frac{1}{4}$-in. plates. The box ring incorporates two rolled rings of $3\frac{1}{2}$-in. square bar stock through which the bolts pass, with $\frac{1}{2}$-inch plates for the sides of the box. Intermittent welds were used throughout.

Fig. 7 shows the structure in the final stages of welding, with cross braces of 4-in. double extra heavy pipe to hold it in shape while annealing. Fig. 5 shows the cage placed on the car of the annealing furnace. These two views plainly show the intermittent welds in the various component parts.

An indication of the accuracy to which this structure was held during welding and annealing may be had from the fact that when this prime focus cage was placed on the mill for machining of its bottom surfaces, the departure from roundness was not greater than 1/16 in.

The great rigidity of this welded structure was demonstrated by the total absence of chatter during

Fig. 16. Partial assembly of tube for boring.



machining of its bottom surfaces, while the tool was working 12-ft. above the boring mill table.

The top and bottom rings of the tube are also of box construction 22 ft. in diameter having pairs of gusset plates at the quarter points for attachment of the tube struts. Fig. 8 shows the top ring during fabrication. It is similar in construction to the bottom ring of the cage. The bottom ring of the tube is somewhat different, by the absence of the rings of rolled bar stock and in the shape of the outer plate, which is conical. This bottom ring may be seen at the left of Fig. 13. Intermittent welds were used throughout these two pieces.

In both these rings, the distance between the groups of gusset plates was held to within 1/16 in. of the drawing dimension. Assembly of the tube was much facilitated by this accurate work. The rings did not depart from roundness more than 3/32 in. after annealing.

The east and west panels of the telescope tube, shown in Fig. 9, are hollow box structures having a bored central hole into which is fitted a flexible gimbal, equivalent to a universal joint, to prevent any distortion due to the closing up of the horseshoe in its east or west position from being transmitted to the tube.

These panels are stiffened with internal diaphragms, as shown in Fig. 10. Some ingenuity was required in selecting the type and position of the welds, as well as the sequence of assembling the plates, so that no welding would have to be done through the handholes. Continuous welding was employed in these panels.

The type of end connection between the panels is shown in Figs. 11 and 12. This method affords some measure of flexibility, and again prevents the transmission of distortions through the tube. The corner brackets at the left of Fig. 11 were merely used for assembling and are not part of the finished structure.

In these panels it was necessary to obtain considerable accuracy in fabrication, and to make allowance for overall shrinkage and possible warping, in order that the finished thickness of the end flanges should not depart appreciably from the required amount. This was accomplished to the extent that the flange thickness was correct to within 1/16 in. after machining.

The north panel of the tube is a box structure of similar design, but with machined faces on both sides to carry a crane and gearing for swinging a subsidiary mirror into place in the center of the tube. It is seen at the far side of Fig. 12.

The south panel, seen at the upper side of the tube in Fig. 12, consists of two half trusses bounding a long slot between the top and bottom rings. This slot is used for the passage of a light beam through the south polar bearing for spectrographic work, in any position of the tube. To facilitate handling and erection, the trusses were each divided into two separate pieces just below the central panels. One of the upper pieces is shown in Fig. 14, in the course of fabrication. Rolled structural sections were used extensively in these pieces.

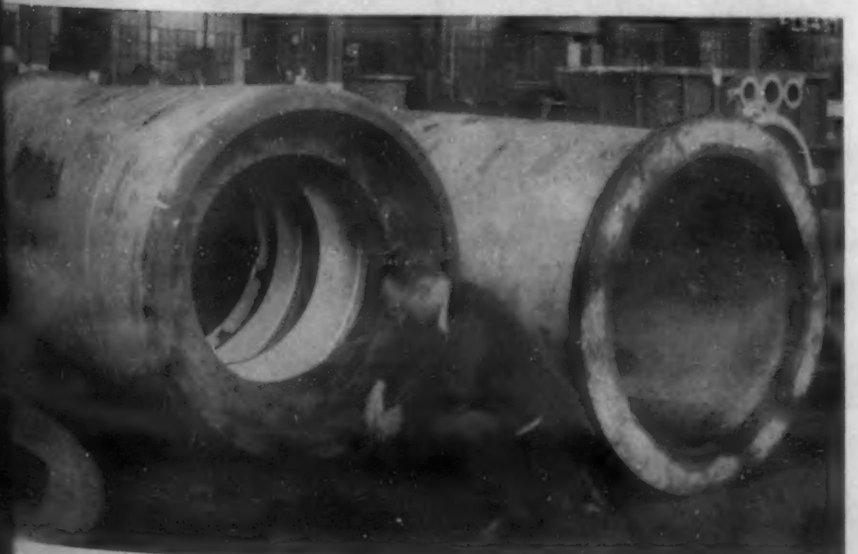
The tapered I section members used in the lower ends of these trusses next to the slot are seen in Fig. 12. They were made as indicated in Fig. 15 by removing a wedge shaped piece from the web of an I beam, bending back the flange, and re-welding.

The upper half of the tube was first assembled in a vertical position, as shown in Fig. 16, for the purpose of boring the holes for the declination axis. It was then turned over horizontally and the parts composing the lower end assembled with it. The completed tube is shown in Figs. 12 and 13. These views clearly show the bolted joints between the central panels and the gusset plate connections to the I section struts. The telescope tube is 46 ft. long and weighs 104,000 lbs., not including the cage.

The weight of the telescope tube is carried on ball bearings in the tubular side members of the yoke. The housings for the spindle bearings are shown in Fig. 17. Each consists of a shell rolled up from $1\frac{1}{2}$ in. thick plate, stiffened with an external flange and several internal rings and welded to a rough machined carbon-molybdenum steel forging forming the seat for the main ball bearing, which is subject to a load of 100 tons.

Carbon-molybdenum steel of the grade used has marked air-hardening tendencies, and to successfully weld it and avoid cracking, it is necessary to preheat the parts to be joined to a temperature of at least 400 deg. F. and to maintain such a temperature throughout the welding operation, and to promptly follow the welding with the stress-relieving operation. This was done by wrapping the forging and mating shell with insulated heating elements, the whole being covered with asbestos lagging to hold the heat until the piece was completed ready for annealing. *(To be concluded)*

Fig. 17. Declination bearing housings.



Creep of Some Chromium-Molybdenum Steels

BY H. D. NEWELL

Chief Metallurgist,
Babcock and Wilcox Tube Co.,
Beaver Falls, Pa.

Some time ago the Allegheny Ludlum Steel Corp., the Babcock and Wilcox Tube Co. and the Climax Molybdenum Co. conducted a cooperative investigation of the effect on creep strength of increasing the molybdenum content of the familiar 4-6 per cent chromium, ½ per cent molybdenum steel. The final report, of which this article is an adaptation, was prepared by Mr. Newell. In connection with the article, we would call attention to the editorial "Man Bites Dog," elsewhere in this issue.—The Editors.

STEEL OF THE 5 PER CENT CHROMIUM, 0.45-0.65 per cent molybdenum type is widely used in the refining industry, and also in steam superheater work. This material has, in many cases, satisfactory corrosion and oxidation resistant properties, but its creep strength is only fair, making excessively heavy tube walls mandatory in the higher pressure installations. As higher creep properties would be welcomed, particularly by the oil refining industry, it was decided to investigate the high temperature creep properties of 5 per cent chromium steels containing 1 to 1.5 per cent molybdenum, to see whether the increased molybdenum content provides any improvement. Silicon was increased somewhat also, to increase the oxidation resistance.

The investigation was a cooperative effort of the Allegheny Ludlum Steel Corp., the Babcock and Wilcox Tube Co., and the Climax Molybdenum Co., with the final report written by Mr. Newell. This article is adapted from that report.

The Steels

The material for test was obtained from two 250-lb. arc furnace melts made expressly for the purpose by Allegheny Ludlum Steel Corp. The ingots were rolled to about ¾-in. rounds and the test bars subjected to an annealing treatment consisting of heating to 1575 deg. F., holding ¾ hr., cooling at the rate of 40 deg. F. per hr. to 1350 deg. F., and thereafter cooling in the furnace.

Chemical analysis, McQuaid-Ehn grain size and Brinell hardness were as follows:

	5%Cr, 1% Mo	5% Cr, 1.5% Mo
Carbon	0.114	0.078
Manganese	0.32	0.25
Silicon	0.73	0.87
Chromium	5.17	5.24
Molybdenum	0.98	1.60
McQuaid-Ehn grain size	7-8	7-8
Brinell hardness	161	160

The structural condition of the creep test specimen materials is illustrated in the photomicrographs, Figs. 1 to 4. The steel containing 0.98 per cent molybdenum has a somewhat finer grain size than that with 1.60 per cent molybdenum, and both materials may be considered well annealed with carbides spheroidized.

Creep Tests

The creep tests were performed at Massachusetts Institute of Technology, under the direction of Professor F. H. Norton. The specimens were of 10-in. gage length, 0.505-in. dia. and 36-in. overall length; the method of testing used by Professor Norton has been described in detail in previous publications and need not be repeated here. Results of the tests giving initial and total elongation, actual creep in in. per in., rate of creep at certain intervals, and final rate of creep are given in Table I. The final creep rates have been plotted to logarithmic coordinates in Fig. 5, from which stress values for creep rates of 0.01 and 0.10 per cent per 1,000 hrs. have been obtained. Values thus obtained are as follows:

Temp. Deg. F	0.01% in 1000 hrs.	0.10% in 1000 hrs.
5 Per Cent Cr, 1 Per Cent Mo		
1000	6,400	9,700
1100	3,100	5,900
1200	1,800	3,500
5 Per Cent Cr, 1.5 Per Cent Mo		
1000	6,400	11,300
1100	3,250	6,400
1200	1,380	3,050

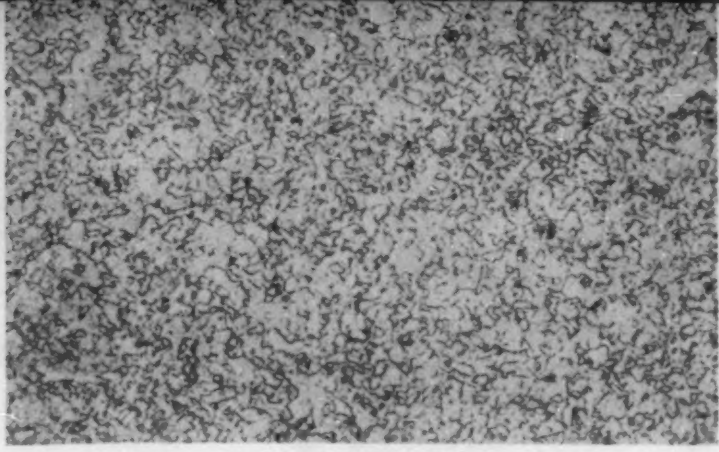
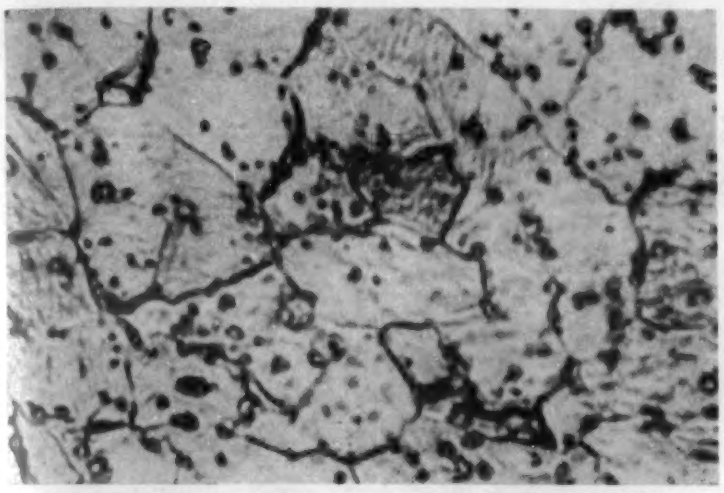


Fig. 1. Structure of the steel containing 5 per cent Cr, 1 per cent Mo, at 100 magnifications. Etched with hydrochloric and picric acids.

Fig. 2. Structure of the steel containing 5 per cent Cr, 1 per cent Mo, at 2000 magnifications. Etched with hydrochloric and picric acids.



Professor Norton has reported final values for the tests that differ slightly from those taken from the log-log plot of Fig. 5. His values are weighed by plotting both final rate per cent per 100,000 hrs. and rates for different time periods throughout the tests. After plotting these points, he then draws a straight line locating it according to his judgment, which is influenced by:

(a) The closeness of any points or point to the 0.01 and the 0.10 ordinate.

(b) The direction of any changes in rate, and also the general shape of the time-elongation curve.

For commercial design purposes these final values are therefore used as the most conservative and considered values. They are as follows:

Temp. Deg. F.	1% in 100,000 hrs.	1% in 10,000 hrs.
5 Per Cent Cr, 1 Per Cent Mo		
1000	6,000	10,000
1100	3,200	5,400
1200	1,800	3,500
5 Per Cent Cr, 1.5 Per Cent Mo		
1000	6,100	11,000
1100	3,300	6,800
1200	1,500	2,800

These values have been plotted to produce the creep stress-temperature curves for the two rates of creep shown in Fig. 6.

Table 1. Creep Test Data on 5 per cent Cr, 1 per cent Mo, and on 5 per cent Cr, 1.5 per cent Mo Steels

Steel	Spec. No.	Test Temp., deg. F.	Test Load, lbs. per sq. in.	Initial Elong. in per in.	Plastic Elong. in per in.	Total Elong.	Creep Rate, per cent in 100,000 hrs.	Time Interval, hrs.	Duration in hrs.
	4	1,000	6,000	0.00032	0.00075	0.00107	0.7	Through Test	6,290
	5	1,000	10,000	0.00040	0.00459	0.00499	15.0	200-800	
							12.0	Final	3,220
	6	1,000	15,000	0.0009	0.0526	0.0535	81.0	2,000-2,600	
							242.0	Final	2,610
	1	1,100	3,000	0.00029	0.00112	0.00141	1.0	1,200-3,000	
							1.0	5,200-7,200	
							0.9	Final	7,150
5% Cr, 1% Mo	2	1,100	6,000	0.00031	0.01143	0.01174	15.7	1,400-2,800	
							12.5	2,800-3,600	
							10.6	Final	7,150
	3	1,100	9,000	0.0004	0.0489	0.0493	750.0	25-380	
							283.0	Final	1,030
	7	1,200	1,500	0.00017	0.00105	0.00122	7.8	40-460	
							0.65	Final	6,280
	8	1,200	3,000	0.00031	0.00458	0.00489	5.3	1,400-2,600	
							3.7	Final	6,280
	9	1,200	4,500	0.0003	0.0304	0.0307	51.0	400-1,600	
							74.0	5,400-7,000	
							38.0	General	6,115
	4	1,000	6,000	0.00035	0.00073	0.00108	0.8	Through Test	6,290
	8	1,000	10,000	0.00042	0.00393	0.00435	5.8	800-2,400	
							4.9	Final	6,280
	9	1,000	15,000	0.0008	0.0312	0.0320	44.0	0-1,400	
							66.0	1,400-3,400	
							48.0	Final	5,950
	1	1,100	3,000	0.00018	0.00134	0.00152	4.5	200-1,000	
							1.5	1,000-1,800	
							0.8	Final	7,150
5% Cr, 1.5% Mo	2	1,100	6,000	0.00038	0.00672	0.00710	13.1	600-1,100	
							7.4	1,400-2,600	
							5.8	Final	7,150
	3	1,100	9,000	0.0005	0.0641	0.0646	341.0	1,300-1,900	
							256.0	Final	2,130
	5	1,200	1,500	0.00005	0.00157	0.00162	5.4	400-1,100	
							2.7	1,100-1,400	
							1.3	Final	3,720
	6	1,200	3,000	0.00018	0.00851	0.00869	11.3	1,200-2,600	
							9.5	Final	6,290
	7	1,200	4,500	0.0004	0.0542	0.0546	56.0	200-1,800	
							101.0	5,000-6,200	Rate increasing
							79.0	Final	6,200

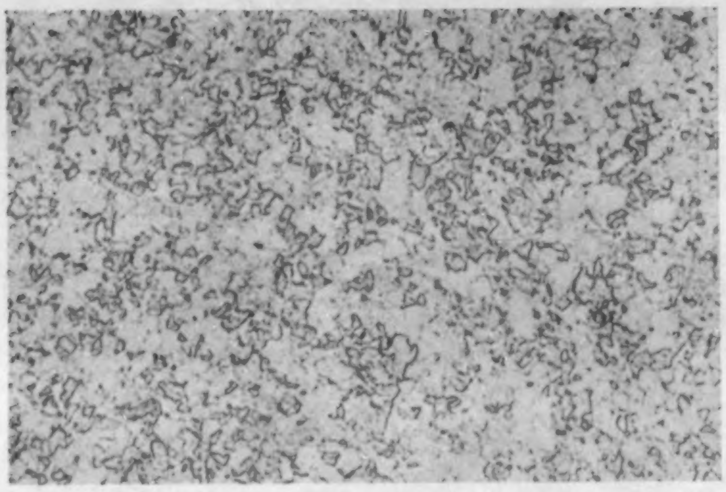


Fig. 3. Structure of the steel containing 5 per cent Cr, 1.5 per cent Mo, at 100 magnifications. Etched with hydrochloric and picric acids.

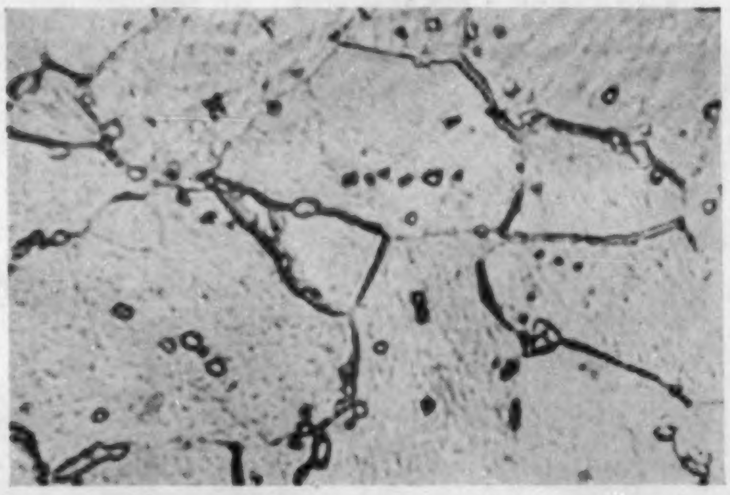


Fig. 4. Structure of the steel containing 5 per cent Cr, 1.5 per cent Mo, at 2000 magnifications. Etched with hydrochloric and picric acids.

Table II. Creep Data on 5% Cr, 0.5% Mo Steel, Taken from Commercial and Technical Literature, Including "Compilation of Available High Temperature Creep Characteristics of Metals and Alloys," A.S.T.M.-A.S.M.E., 1938

Source of Data	Rate per 1,000 hrs.	1,000 deg. F.	1,100 deg. F.	1,200 deg. F.
B & W Tube Co.	0.01%	7,200	2,400	900
	0.10%	9,200	4,800	1,800
Timken Steel & Tube Co.	0.01%	7,600	3,200	1,700
	0.10%	10,100	5,800	2,800
National Tube Co.	0.01%			
	0.10%	9,200-10,250	4,800-6,000	1,800-3,300
Battelle Mem. Inst.	0.10%		4,200 (0.139 C)	
	0.10%		5,170 (0.18 C)	

Table III. Comparison of Creep Value Ranges for 5% Cr, 0.50% Mo Steel and for Similar Steels with 1.0% and 1.5% Mo

Steels	Rate per 1,000 hrs.	1,000 deg. F.	1,100 deg. F.	1,200 deg. F.
5% Cr, 0.50% Mo	0.01%	7,200- 7,600	2,400-3,200	900-1,700
	0.10%	9,200-10,250	4,200-6,000	1,800-3,300
5% Cr, 1.0% and 1.5% Mo	0.01%	6,000- 6,400	3,100-3,300	1,380-1,800
	0.10%	9,700-11,300	5,400-6,800	2,800-3,500

Discussion of Results

The increase of molybdenum from the usual 0.50 per cent to 1.0 per cent in steel containing 2 per cent chromium or thereabouts effects a decided improvement in creep strength properties. In that case, however, the alloy content is sufficiently low so that the steel approaches a pearlitic type. Further, it can be purposely made of coarse grain type, which is helpful in resisting plastic flow, and the extra molybdenum tends toward increased resistance to spheroidization and coalescence of the carbides under temperature. Such steel, even with the preferred 3-6 A.S.T.M. grain size, has good ductility and toughness in the annealed condition. The highly beneficial effect on creep properties of increasing molybdenum from 0.50 per cent to 1.00 per cent is indicated by the following creep values:

Material	Rate in 1,000 hrs.	1,000 deg. F.	1,100 deg. F.	1,200 deg. F.
2% Cr, 0.50% Mo.	0.01%	6,300	3,325	1,075
	0.10%	11,000	5,875	3,400
2.25% Cr, 1% Mo	0.01%	7,600	4,910	2,510
	0.10%	16,350	9,200	4,175

The 5 per cent chromium type, however, is naturally cementitic, *i.e.,* carbides spheroidize rapidly on annealing, and in fact it is rather difficult to produce a lamellar pearlitic structure even with special thermal treatments. Grain size is, in general, small and it is difficult to effect much change in this feature irrespective of melting practice. Attempts to coarsen structure by thermal treatments to improve creep

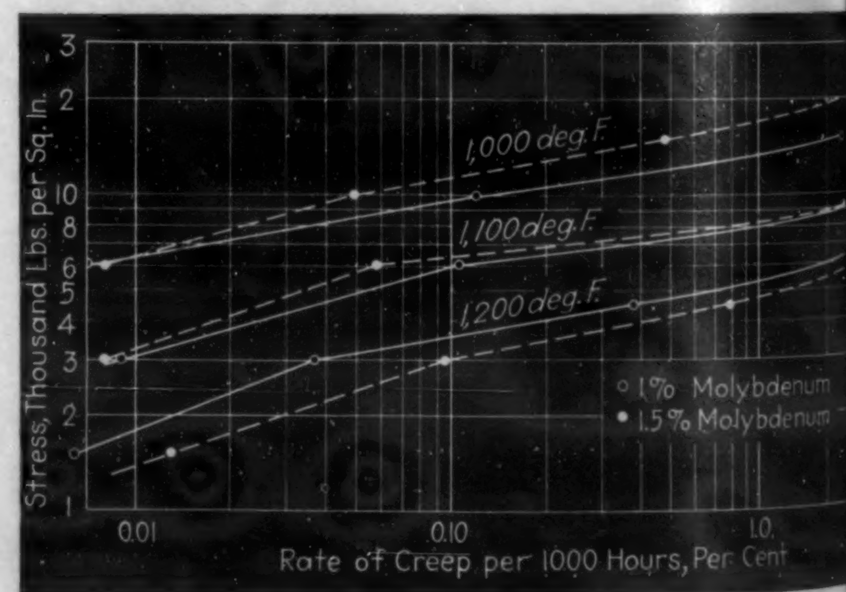


Fig. 5. Creep rate curves at given temperatures of 5 per cent Cr, 1 per cent Mo, and of 5 per cent Cr, 1.5 per cent Mo steels.

properties detract from the effectiveness of molybdenum in suppressing temper brittleness, and lead also to reduced ductility and toughness. In consequence, any improvement in creep properties from additional molybdenum in the 5 per cent chromium type must come mainly from a stiffening of the ferrite matrix with but slight benefit from molybdenum combining with the carbide to produce a more stable form.

In Table II are listed available data from various sources on wrought 5 per cent chromium, 0.50 per cent molybdenum steel, annealed. These data have been summarized to give typical ranges of creep values, and these ranges are presented, along with corresponding ranges for the higher molybdenum steels investigated here, in Table III.

There does not appear to be any significant advantage for the higher molybdenum alloys as against the standard 0.50 per cent molybdenum alloy throughout the temperature range studied, although the higher molybdenum alloys show values consistently toward the high side of the range of variation for the 0.50 per cent molybdenum steel, except for the 0.01 per cent rate at 1000 deg. F. There is an indication of slightly better resistance to creep of the 1 per cent and 1.5 per cent molybdenum steels at 1100 and 1200 deg. F., but there is not sufficient difference in stress values to justify the increased cost of the addition over the usual 0.50 per cent molybdenum addition.

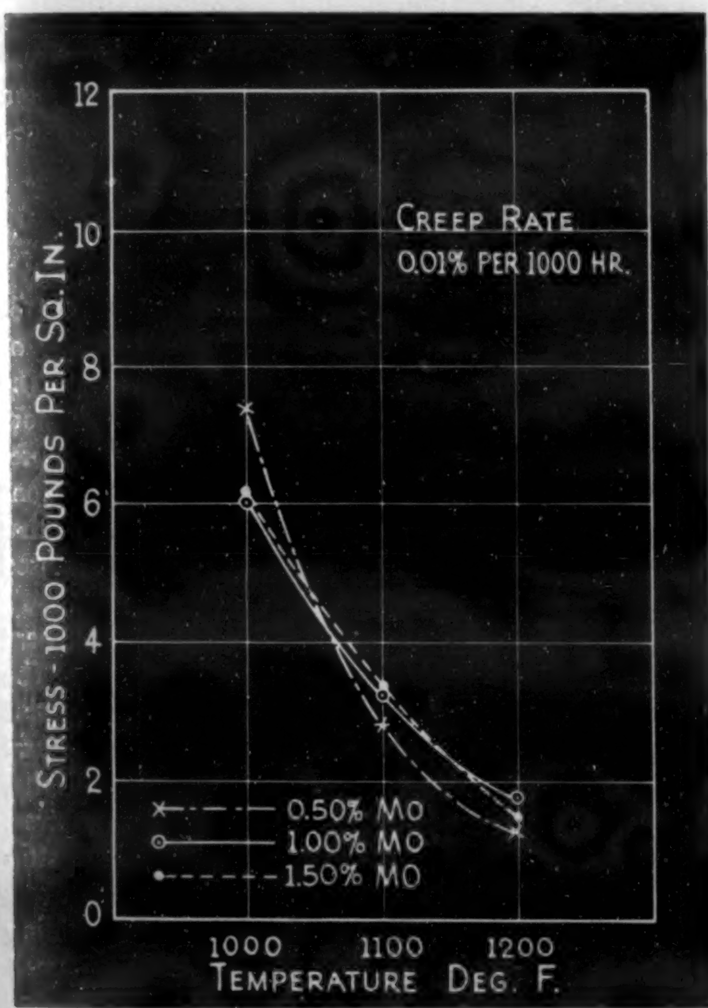


Fig. 6. Creep stress curves at a creep rate of 0.01 per cent per 1000 hrs. of 5 per cent Cr steels with 0.50, 1.0 and 1.5 per cent Mo.

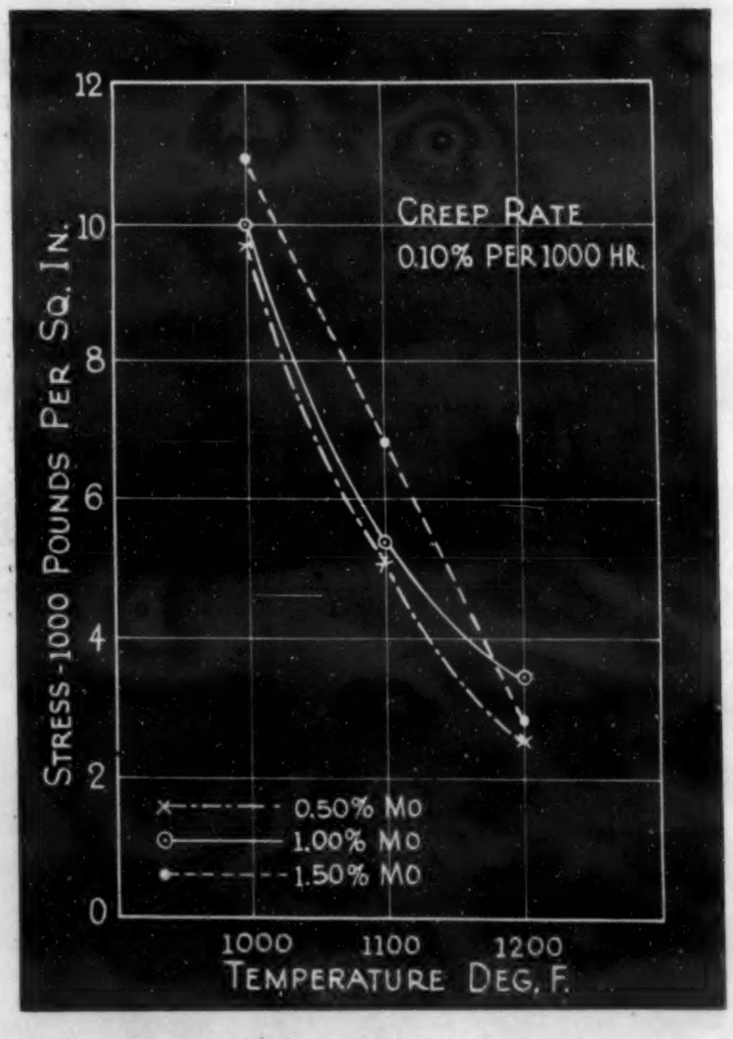


Fig. 7. Creep stress curves at a creep rate of 0.10 per cent per 1000 hrs. of 5 per cent Cr steels with 0.50, 1.0 and 1.5 per cent Mo.

Fatigue Problems in Structural Designs

BY A. V. KARPOV

Consulting Engineer, Grant Bldg., Pittsburgh

This is the sixth and last article in our series on Fatigue. Owing to its length, it has been necessary to divide it in two portions. The five other articles in this important and valuable series have appeared in the six preceding issues and the origin and general scope of the series was fully outlined in an introductory statement to the first article in the May issue.

The series was as follows: "Fatigue of Metals—Developments in the United States" (May and June); "Fatigue Problems in the Aircraft Industry" (July); "Fatigue of Light Metal Alloys" (August); "Fatigue Problems in the Electrical Industry" (September); and "Some Fatigue Problems in the Railroad Industry" (October).

In this article, the author states that insofar as bridge trusses and in particular modern welded bridges are concerned, no satisfactory design can be made unless proper consideration is given to fatigue problems.—The Editors.

THE WORK OF THE METALLURGIST developing and investigating new alloys, the work of the material tester who determines the different properties of the alloys developed by the metallurgist are only preparatory steps. The ultimate purpose obviously is to use the alloy in a structure where its application will be more advantageous as compared with other alloys.

The problem of the structural designer is to utilize the results of the work of the metallurgist and material tester and to determine which alloy will be the most suitable for each structural element. The criterion of suitability is established by the comparison of the behavior of the material which was disclosed in the past by tests made on specimens, models and parts of or even complete structures with the probable future behavior of the proposed structure and its elements. The same basic principles that are used in the design of non-moving structures—as, for instance, bridge trusses—are applied in the design of railroad rolling stock, automobile frames, trusses of lighter-than-air ships, or structural members of airplanes, etc.

Stress-Resisting Capacity a Fundamental Property

The most fundamental property of any metal or alloy which makes possible its utilization in any of such structures is its stress-resisting capacity. The first comparison therefore is made between the more or less known behavior of the selected material previously determined under different stress conditions and its expected behavior under stress conditions that probably will be encountered if this material is used in a particular structural element.

The past or future history of a structural element may be shown by a "Time-Stress" diagram. The loads applied to a structure are reflected in strains with resulting stresses developed in each structural element. These stresses may be shown graphically, using time as abscissas and, for instance, the stress in the outer fiber as ordinates, resulting in long strip diagrams of the order shown in Figs. 1, 2 and 3.

Fig. 1 may be considered typical for a building column in which the stress variations are very small and of rather long duration, due primarily to changes in temperature.

Fig. 2 may represent the conditions of a part of a bridge truss in which the dead load stress is comparatively small and the super-imposed temperature and live load stresses represent the major part of the total stress. In such cases the irregular and sharp stress peaks and occasional overstress peaks may be separated by substantial recovery periods.

Fig. 3, finally, may represent the stresses of the part of an engine in which the dead load stress is negligible and sharp stress peaks are applied in rapid

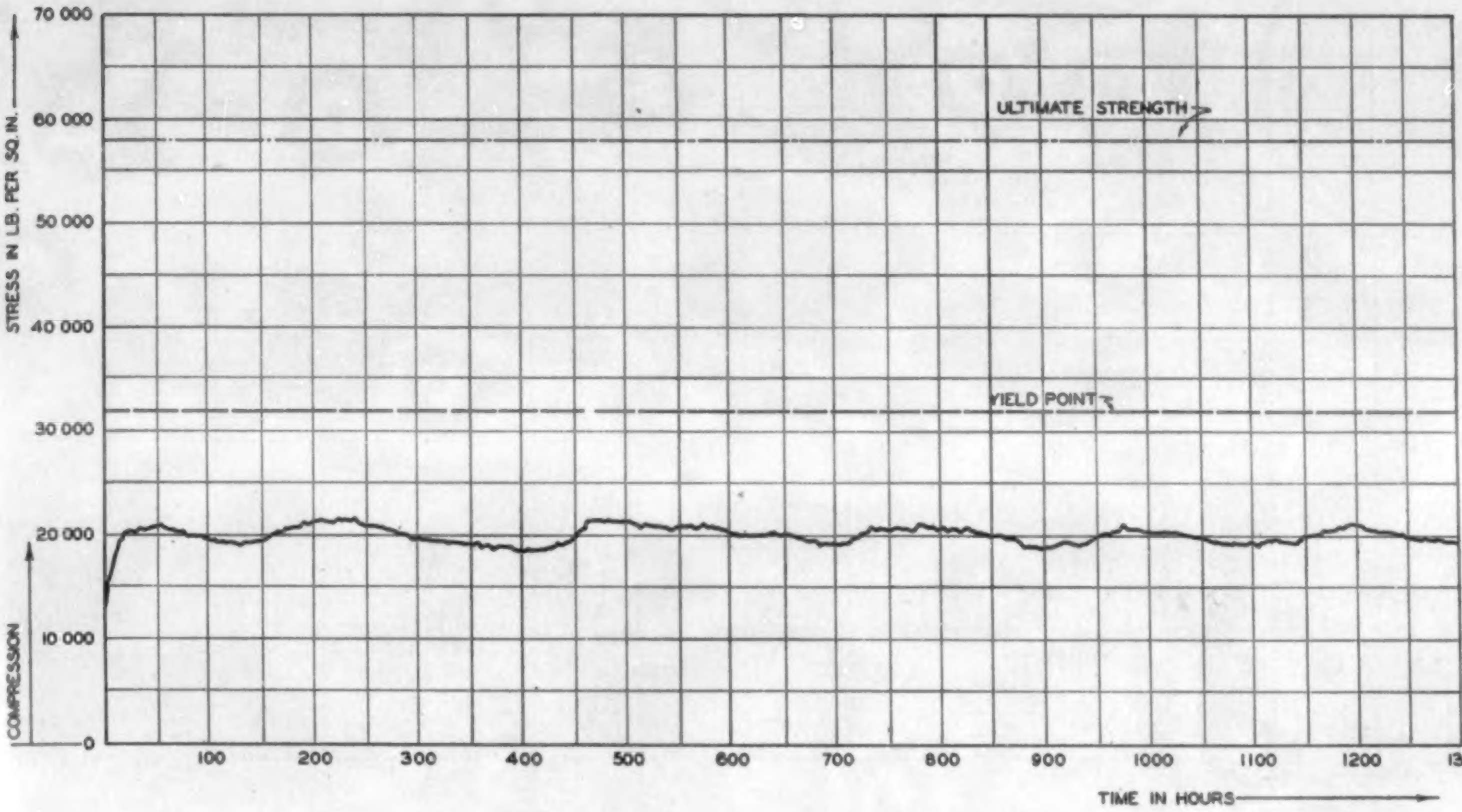


Fig. 1. Time-stress diagram—building column.

succession with no appreciable recovery time between the single stress applications but with a longer recovery period between two series of stress peaks due to time intervals when the engine is not in operation.

The loadings that produce the stresses and the stresses in each diagram may be represented by two parts, the permanent or constant part and the varying part. The customary division of load into dead and live loads represents an attempt to show in a very simplified way the probable future load conditions, but in most instances does not correspond to the stress divisions of a "Time-Stress" diagram.

I. PERFECT DESIGNS

THE perfect design would require the exact determination of the future time-stress diagram of each structural element and the testing of the material under exactly the same time-stress regime. Perfection would be attained if during the testing of the material under such regime no failure would occur. An extension of the testing time beyond the expected life span of the structure or a slight increase in stress brought about by a slight decrease in dimensions of the structural element should result in failure. The amount of material used in such design should correspond precisely to the service conditions. The safety factor of the structure being above unity during the time of service and diminishing to unity at the end of the expected life.

With a very few exceptions, such procedure is obviously impossible and compromises are necessary that will make the design possible and practical. Each compromise will mean the use of an excessive amount of material resulting in a safety factor above unity at the end of the expected life.

Economic considerations determine the broader limits within which such compromise must fall. Within these economic limits there is left a considerable leeway where the choice may be governed by the viewpoint, engineering habits, personal inclinations, etc. There is no doubt, however, that with time the economic limits are moving closer to the perfect design, mostly due to the increase in engineering knowledge which makes possible a more exact determination of the probable future time-stress regime of the structure and the past time-stress behavior of the material.

II. ENGINEERING DESIGN

IN most cases the future time-stress regime cannot be exactly determined. In the comparatively few cases in which this can be done, it probably would be out of the question to attempt a test of materials under varying load applications for a length of time corresponding to the proposed life of the structure. Accelerated tests are the only practical solution.

The engineering problem, therefore, would be to determine the approximate future time-stress regime

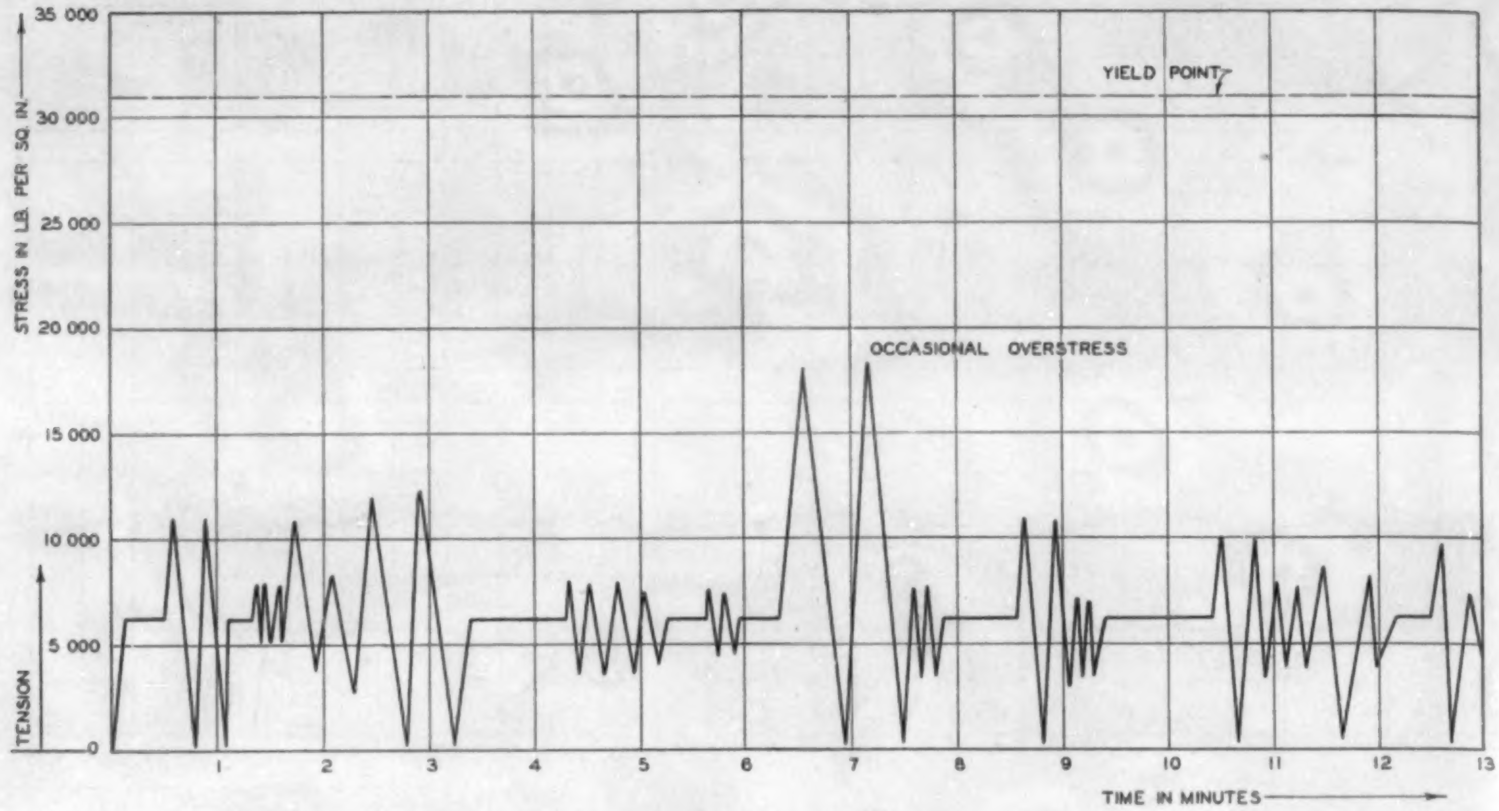


Fig. 2. Time-stress diagram—bridge truss member.

of each structural element and compare and correlate it with the past time-stress behavior of the material determined by means of greatly accelerated tests.

In determining the time-stress regime, two major difficulties are encountered. First, the exact determination of future loading conditions; second, the determination of the actual stress at the highest stressed point of the structural elements. The uncertainties of both of these determinations, coupled with the uncertain properties of materials, make it necessary to introduce safety factors, the values of which may be large.

The simplest and most frequently used approximation is not to use the whole time-stress regime curve as the basis of comparison, but to pick out only one point on this curve—the point of the maximum stress that may occur during the whole life of the structure. The more exact method would be to determine the limits within which the time-stress curve will fall. A still more exact method would be if the useful life of the structure can be ascertained and the number of load applications of different intensity determined.

With the gradual development of design methods came the changes in the appreciation of the importance of different material constants. At first the ultimate strength was considered as the governing criterion in design. The designing stress was limited to a definite portion of the ultimate strength. Afterwards came the realization that for materials exhibiting a definite yield point, a relation between the design stress and yield point strength is of more importance. Finally, the present attitude is developing that, although the ultimate strength and yield point are fundamentally important properties of metals, nevertheless, in many instances the design stress should be governed by the fatigue properties of the material. Conversely the new alloys should be considered more in the light of their fatigue properties and not entirely in the light of their ultimate and yield point strength.

If the time-stress regime is of the character shown on Fig. 1, a design procedure which presupposes a constant static load during the whole life of the structure and neglects the time element and the fatigue properties of the material may be entirely justified.

There is very little doubt that the designs of structural elements to be subjected to time-stress regimes shown in Fig. 3 cannot be based successfully on the assumption of static loads. Some doubt, however, has been expressed in the past with reference to the design assumption of structural elements that will be subjected to time-stress regimes of the order shown in Fig. 2.

The comparison of the probable future time-stress regime with the more or less known past time-stress behavior of the material is the most fundamental designing problem.

The investigation of fatigue phenomena is of importance not only because it discloses properties of the material which are not well understood but also because it brings squarely before the engineer the importance of the time element. That an engineering structure should be in service for a certain period of time is always obvious. However, very little has been

recognized as to how the time element should influence the design. The structures of the past were designed more or less on the assumption that, if the structure is satisfactory during the initial loading period, it should be satisfactory during an indefinite period of time. Little consideration, if any, was given to the deterioration of metals by corrosion and to the necessary protection that will prevent such deterioration and to the reduction of strength due to fatigue.

Life of Structures

The modern tendency is to shorten the life of engineering structures, but at the same time to make the structure as perfect as possible during its shortened life. As a logical sequence of such tendency there is neither an economic or engineering justification for building a structure that could stand, say, for centuries when its useful life will last only decades. The modern airplane with its maximum life of about 5 yrs., or the automobile with a somewhat longer useful life, are the extreme representations of the tendency to shorten the life of engineering structures. At the same time, however, these engineering structures of shorter life are brought to a state of perfection which would have seemed impossible even a few years ago.

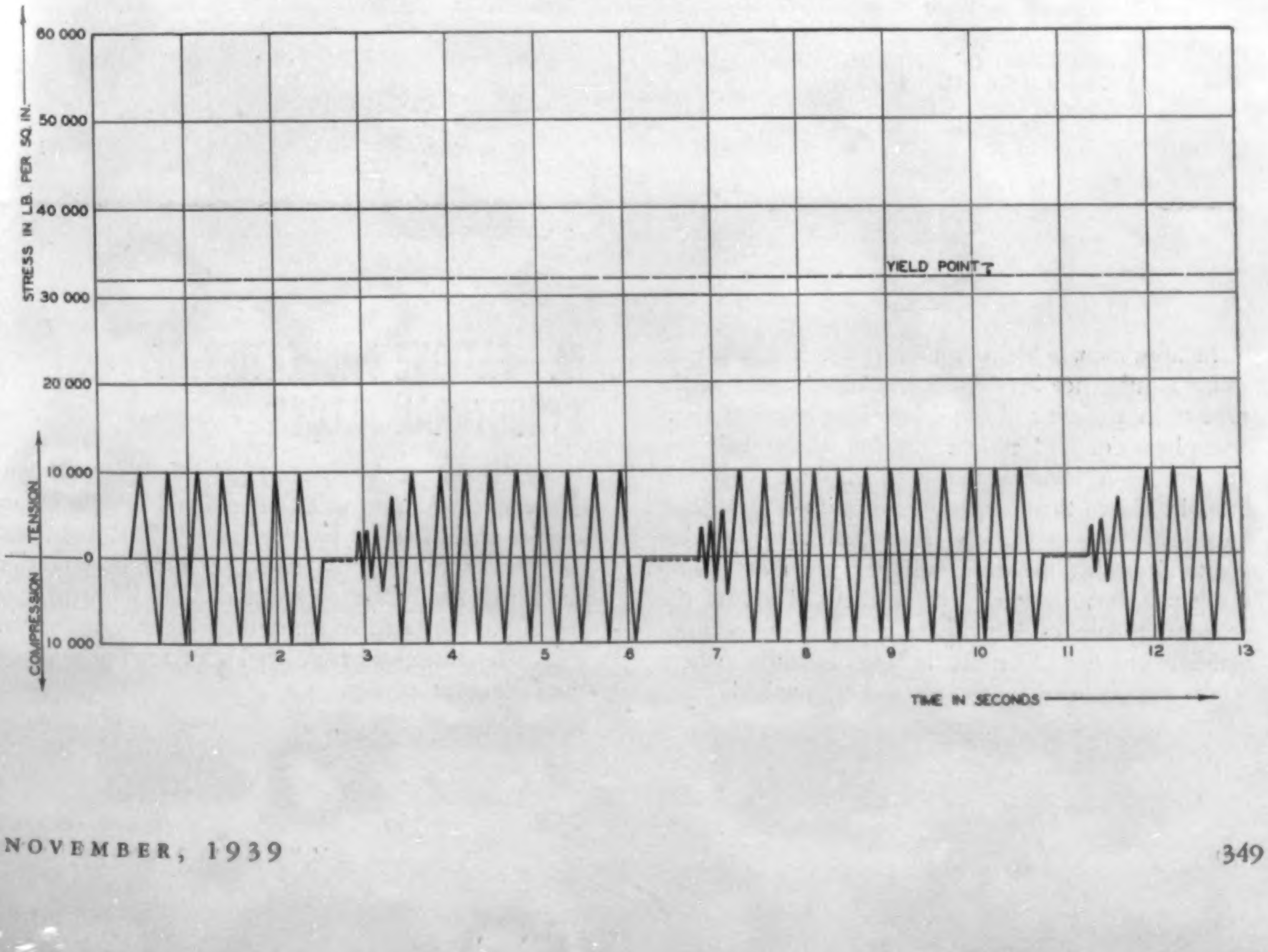
Modern engineering problems are more complicated than in the past. The aviation, the automobile industry, the mass production and mass utilization and consumption of engineering structures are based on a more refined and more exact design.

Refinements in Design

The refinements in design are reflected in a closer scrutiny as to the conventionally evaluated and the actual stress and the expected and actual performance of the structural materials. The conventionally assumed and the actual safety factors could be quite different in the past. The refinements in engineering tend to bring together these two different safety factors.

Besides the conventional factors that characterize a metal, such as ultimate strength, elongation and yield point, a number of additional factors must be considered. The conventional design factors either were of a simple nature or were arbitrarily simplified to such an extent that they could be expressed by a simple coefficient. Many of the new factors are of such complexity that they cannot be covered by a simple coefficient, and it becomes necessary to develop more complicated methods of characterizing the different properties. The more refined engineering application of materials is more difficult, and after the metallurgist and material tester are through with their work and submit their results, the engineer in many cases cannot apply them directly. A long-drawn investigation may be necessary before the material may be applied to the best advantage in the particular conditions of a particular structure.

Fig. 3. Time-stress diagram—engine part.



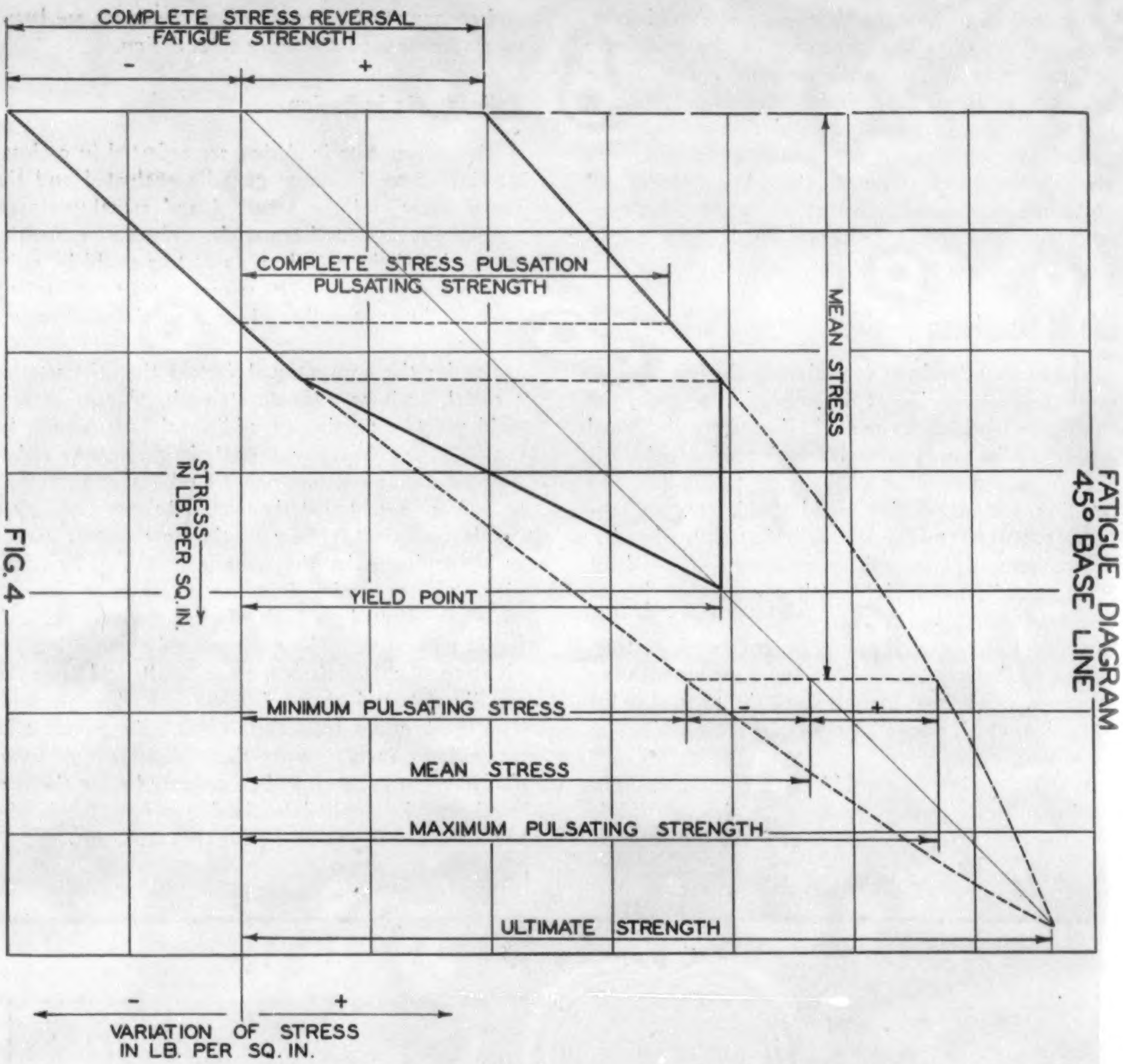


Fig. 4. Fatigue diagram—45 deg. base line.

In approximate designs there must necessarily be quite a difference between the assumed curve of the time-stress regime and the determined curve of time-stress behavior. More extensive knowledge will permit the use of construction in which these curves are brought closer together. Uncertainties and lack of knowledge will necessarily force these curves farther apart. Probably the most radical method of closing the gap between these curves without obtaining the necessary theoretical knowledge is the testing of automobiles on the different testing grounds, where results are obtained by the cut and try method.

III. FATIGUE PROPERTIES OF STRUCTURAL ALLOYS

THE fundamentals governing the fatigue problems are so little known that no rational fatigue theory can be established at present.

Literally millions of tests are run, innumerable specimens are broken, but the definite knowledge is limited to the fact that the surface conditions and the stress concentrations have an important influence on the fatigue properties.

The fundamental problem of the relation between the chemical composition of the alloy and its fatigue properties is probably even less understood than the relations between the chemical composition and the other physical properties of metals that are important in engineering constructions.

Under these conditions the study of the fatigue phenomena and their application to engineering designs remains a purely experimental problem. After an alloy is developed and most carefully investigated, all the information that is put into the hands of the designer can be summarized in a number of empiric and not correlated coefficients that give a representation of the behavior of the simple testing specimens. The question of how the alloy will behave in an actual design cannot be answered directly. It is only possible to infer that a certain alloy will probably behave better or worse as compared with some other alloy.

Probably the most disturbing factor from the engineering viewpoint is the present method of supplying fatigue data with reference to the surface conditions.

The fatigue strength depends on the highest stress developed in the specimen. If, therefore, stress concentrations are made possible as for instance by either having the surface rough or by a sharp notch, the fatigue strength of the specimen will be lowered, not due to lowering of the fatigue strength of the material but mainly due to the actual stress being higher than the assumed stress.

The fatigue problem therefore should be considered as a combined problem of actual surface stress and fatigue strength. At present, however, the material tester prefers to take the easier road and to give fatigue strength data, neglecting the stress concentrations.

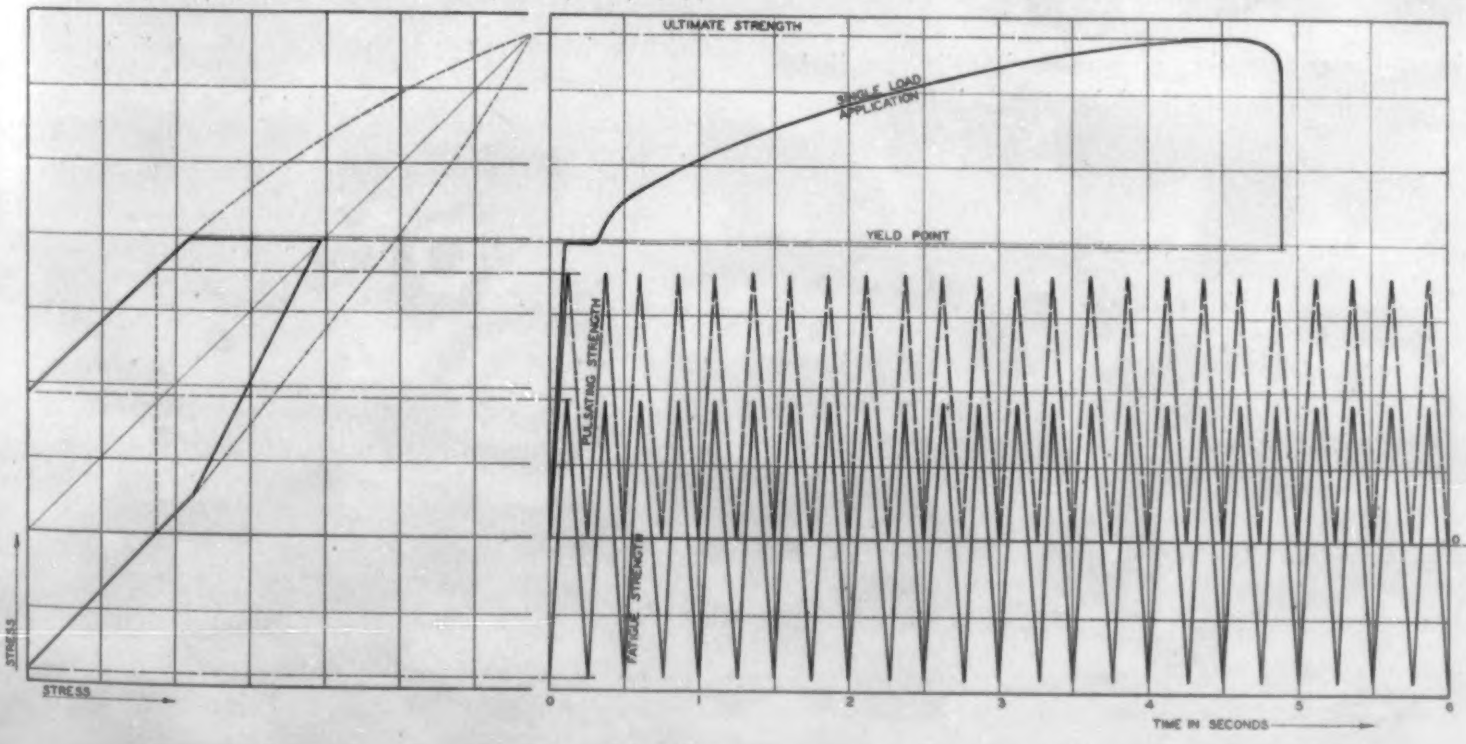
The ordinary fatigue tests are run on highly polished specimens. The results of such tests can be directly applied only to machine parts that are highly polished, and means are taken to preserve the surface in such condition during its service.

The next more or less standard fatigue test is the test of a notched specimen. The notching produces stress concentrations, and the results of such tests are not given in terms of the increased stress but, to the contrary, the usual and rather confusing statement is made that the fatigue strength of the material decreased. On the basis of such definition each material has a number of different fatigue strengths depending on its surface conditions. From an engineering viewpoint a certain distinction should be made between the fatigue strength depending on the surface conditions, such as highly polished, machined, with mill scale, etc., and the reduced stress-resisting capacity of the specimens which is not due to reduced fatigue strength but due to the fact that the actual stress is higher than the stress that was assumed in determining the fatigue strength.

Stress-resisting Capacity of Structural Alloys

For a definite metal the stress-resisting capacity may be represented, within the limits of engineering approximations, at definite surface conditions and for

Fig. 5. Developed fatigue diagram—time-stress representation.



a definite kind of stress, by a 45-deg. base line diagram shown in Fig. 4.

Under gradually increasing static load, the failure will occur at the highest point of the diagram which corresponds to the ultimate strength of the material. This point and the yield point are the points in the diagram which do not depend on the surface conditions of the material.

From the engineering point of view, in nearly all structural parts with a very few exceptions, as, for instance, springs, the structural element must be protected not only from failure but also from excessive deformation. Therefore, the parts of the diagram which can be applied practically will be limited by the yield point for alloys exhibiting a definite yield point, or by some more or less arbitrary chosen value for alloys that do not exhibit a definite yield point.

The points on such a diagram that should be definitely established are the fatigue strength corresponding to complete stress reversal and the strength that may be called "pulsating strength" corresponding to a complete stress pulsation from zero to a maximum. Connecting these points by straight lines will result in a diagram of sufficient accuracy for practical applications.

Such a 45-deg. base line diagram could be developed in a number of stress-time diagrams, shown on Fig. 5, indicating that tests proved that specimens cut out of the particular material under particular surface conditions can stand stresses applied at high frequency and without a recovery period. The three typical time-stress diagrams shown in Fig. 5 indicate that as long as the static load is lower than the yield point, or the dynamic load is kept within certain limits for pulsating load and within certain but smaller limits for complete stress reversal no failure should occur.

Limited Stress-resisting Capacity

From the engineering viewpoint there is very little difference if the static load be applied for a comparatively short or indefinitely long period of time. The stress must be kept below the elastic limit and, if no creep occurs and if proper upkeep and maintenance are provided, the purely statically loaded structure should stand for an indefinite period of time as well as for a short time.

The conditions are radically different under dynamic loading. The stress-resisting capacity diagram can be drawn either for an indefinite number or for a limited number of load applications. Decreasing the number of load applications will not influence the yield point of the diagram, but as shown in Fig. 6 the non-failure stress limits will grow in so far as dynamic load applications are concerned.

A definite distinction in definition should be made to differentiate between the limited and unlimited number of load applications. The expression "Fatigue Strength" and "Pulsating Strength" should be used in case of limited number of load applications, and "Pulsating Limit" and "Endurance Limit" in case of unlimited number of load applications.

In dealing with the stress-resisting capacity of an alloy, the typical coefficient may be established for each kind of stress as bending, tension-compression, shear, as given in the Table.

TABLE OF STRESS-RESISTING CAPACITY OF ALLOYS

Major stresses	Bending Tension—Compression Shear or torsion
Surface conditions of no importance	Single Load Application Ultimate strength Elongation Yield point (if any)
Surface Conditions of Major Importance:	
Arbitrary classification of surface conditions	Mirror polished Polished Machined Sharp circular notch Mill scale on Under ordinary water Under salt water
Limited number of load applications Pulsating strength Fatigue strength	Unlimited number of load applications Pulsating limit Endurance limit

(To be concluded)

METALLOGRAPHIC IDENTIFICATION OF

Ferro Magnetic Phases

BY H. S. AVERY, V. O. HOMERBERG, and EARNSHAW COOK

Metallurgical Department, American Brake Shoe & Foundry Co., Mahwah, N. J.

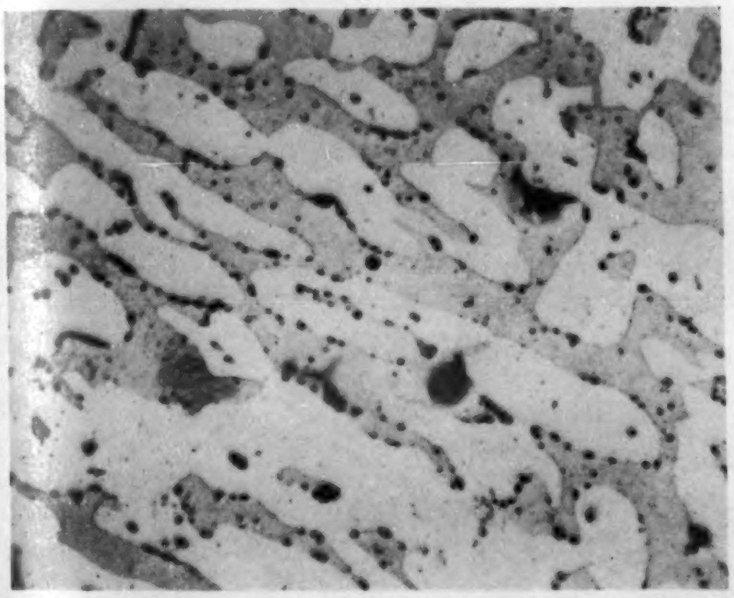
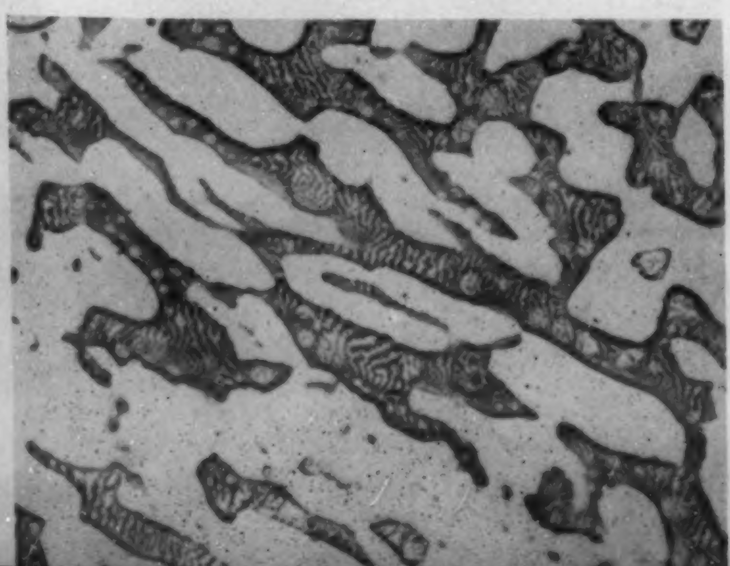


Fig. 1.—Heat resistant alloy: C 0.11, Mn 1.08, Si 0.85, Ni 11.6 and Cr 28.2 per cent. Creep test for 336 hrs. at 1800 deg. F. Etch: 30 secs., 1:1, $HCl:H_2O$ containing 1 per cent Rodine. 250X

Fig. 2.—Magnetic colloid pattern. Same area as Fig. 1. Etch: None. 250X.



This article will be of wide interest to all metallurgists working with heat-resistant and other austenitic alloys. It is of advantage to be able to identify magnetic constituents in a non-magnetic matrix. The technique developed for this purpose makes use of a colloidal pattern which has proved especially useful for the detection of ferrite in austenitic Ni-Cr-Fe alloys.—The Editors.

THE POSITIVE IDENTIFICATION of magnetic constituents in a non-magnetic matrix is greatly facilitated by a colloid pattern technique. If the polished surface of a metallographic specimen is covered with a thin colloidal suspension of magnetic particles, application of a magnetic field will cause a visible concentration of the colloid over the magnetic areas, and a characteristic mosaic pattern frequently results.

This technique, developed by Bitter, Elmore, and McKeehan, has proved especially useful for the detection of ferrite in austenitic nickel-chromium-iron alloys. Examples showing typical results for three different alloys are appended.

Fig. 1 is a specimen of 28 per cent Cr-12 per cent Ni heat-resisting alloy, etched with hydrochloric acid diluted 1:1 with water and containing an inhibitor. The ferrite is gray in a white austenitic background. An application of Murikami's reagent which would clearly reveal carbides has been omitted on this specimen. The small dark spots at the junctions of the ferritic and austenitic areas are apparently etching pits.

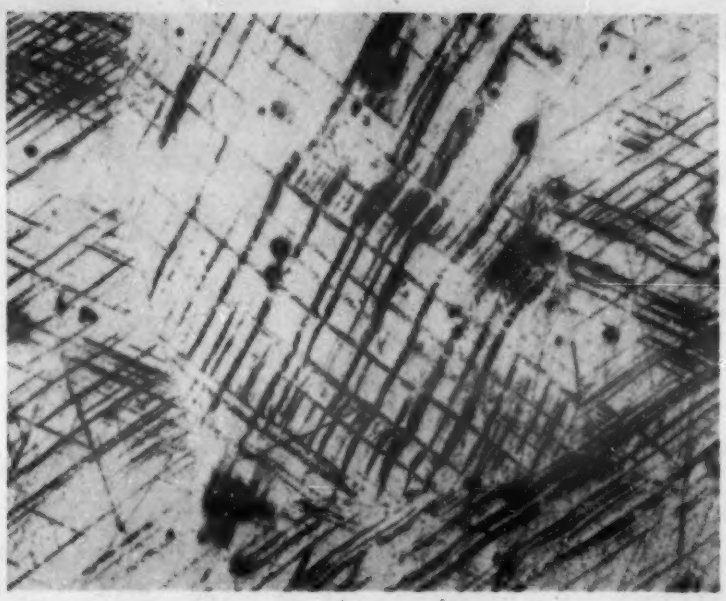


Fig. 3.—Austenitic manganese steel: C 0.40, Mn 13.80, Si 1.34 per cent. Water quenched from 1800 deg. F. and subsequently cold worked by tension. Etch: (1) 15 sec. 3 per cent nital. (2) alcohol rinse. (3) 10 sec. 10 per cent HCl in ethyl alcohol. (4) alcohol rinse. 250X.

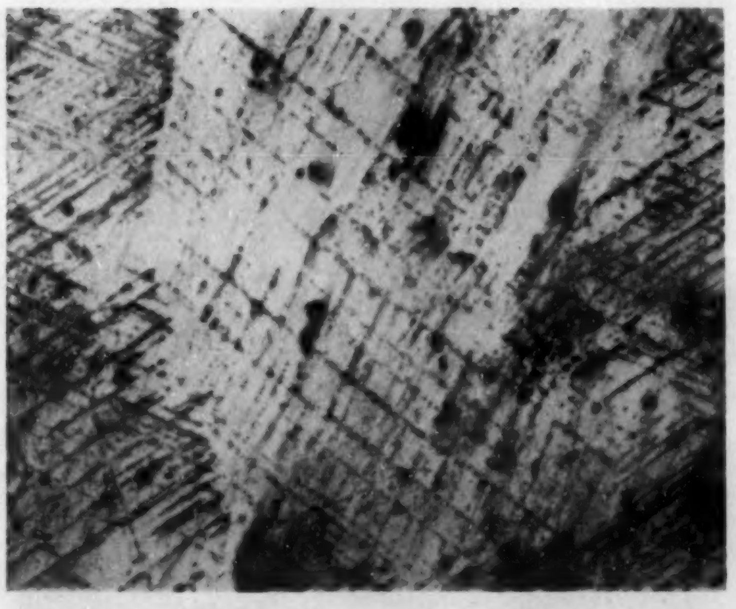


Fig. 4.—Magnetic colloid pattern. Same area as Fig. 3. Etch: None. 250X.

Fig. 2 shows the identical area, *unetched*. The areas of concentration without respect to pattern are useful for metallographic identification. The colloid mosaic pattern formed by an applied magnetic field clearly defines the ferritic areas. The pattern is confined to the magnetic constituents and is characteristic of the procedure. Reversal of the field causes a change in its appearance best described as a photographic negative of its previous configuration. A discussion of the significance of the colloid arrangement is available in the list of references appended.

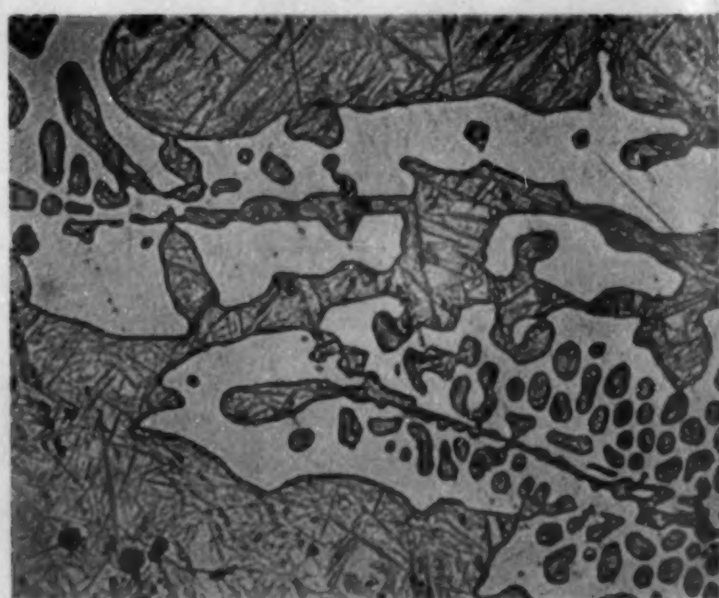
Fig. 3 shows a cold worked specimen of low carbon, austenitic manganese steel cut from the gage length of a tensile bar after testing. The usual deformation lines and grain boundaries are developed by a combination nital-HCl etch. (The alcoholic HCl reagent removes the dark oxidation product produced by nital.) The unetched background is austenite.

Fig. 4 illustrates the effect of the colloid technique on the same area, unetched. The visual evidence of deformation is apparently due to the precipitation of a magnetic phase on crystallographic planes of the austenite.

Fig. 5 is the structure of a nickel-chromium cast iron as revealed by etching with a picral-nital mixture. The very hard, chromium-rich cementite is white against an acicular background of partially transformed austenite. This is from a casting allowed to cool in the mold.

Fig. 6 is the identical area, unetched, under the magnetic colloid. The magnetic nature of the cementite and the apparently different crystallographic

Fig. 5.—Ni-Cr cast iron: C 3.44, Mn 0.65, Si 0.77, Ni 3.96 and Cr 2.02 per cent. As cast structure. Etch: 25 sec. 1:1, 4 per cent picral:2 per cent nital. Without the colloid pattern. 250X.



orientation of the particles (as indicated by the different arrangement of the colloid pattern) in each of the two groups is clearly illustrated. The background shows the presence of a magnetic phase that follows somewhat the acicular pattern of Fig. 5.

The magnet, used to produce patterns, is shown in Fig. 7. A soft steel core was machined to fit snugly into the base of the bakelite sample mounting. With 2300 ampere turns, a satisfactory field is produced. In many cases, a weaker field produces better patterns, and a method of control is desirable. A step down transformer operated from the 110 volt A.C. line, with a copper oxide rectifier, is a satisfactory source of direct current; control by a continuously variable auto-transformer of the "Variac" type in the primary side is recommended. A storage battery with series rheostat may also be used.

Manufacture of the suspension presents occasional difficulties. It may be obtained by the colloid milling of very finely ground magnetite or siderac (magnetic gamma Fe_2O_3). Colloidal magnetite can also be prepared from chemical solutions, as explained by Elmore.[7] A protective agent such as gum arabic or soap is used to stabilize the sol.

> "To make the new colloid, first prepare a coarse, flaky precipitate of magnetite by Lefort's method; dissolve 2 grams of $FeCl_2 . 4H_2O$ and 5.4 grams of $FeCl_3 . 6H_2O$ (or equivalent amounts of the sulphates) in 300 cc. of hot water and add with constant stirring 5 grams of NaOH dissolved in 50 cc. of water. Filter to remove salt and excess sodium hydroxide. Rinse precipitate in filter several times with water and finally once with 0.01 N HCl. Then transfer the precipitate to one liter of 0.50 per cent soap solution and boil for a short time. The former precipitate will now have become entirely colloidal with the exception of a very small quantity of undispersed oxide which should be removed by filtering hot. It is interesting that the success of the method depends entirely on the peptization of the precipitate with HCl before it is added to water containing soap which serves as a protective colloid. A drop or two of the colloidal magnetite placed on the magnetized specimen will give an ample supply of sol particles for forming a pattern."[7]

Fig. 6.—Magnetic colloid pattern. Same area as Fig. 5. Etch: None. 250X.

For metallographic purposes, a drop of the magnetic sol is placed on the polished specimen and covered with a microscope cover glass. Elmore recommends protecting the polished surface with a thin layer of celluloid-amyl acetate lacquer as well. In the field of the magnet, concentrations of the colloid particles will delineate the magnetic phases. Interruption or reversal of the current may be helpful in detecting very small or narrow magnetic areas.

It should be noted that metallurgical microscope objectives are corrected for use without a cover glass. Unless homogeneous immersion is employed, it is desirable to confine the technique to low and medium magnifications (100X to 250X) if sharp definition is required.

The assistance of Dr. W. C. Elmore in developing the colloid method as a metallographic procedure is gratefully acknowledged.

References:

1 "On Inhomogeneities in the Magnetism of Ferromagnetic Materials," by F. Bitter, *Physical Review*, Vol. 38 (1931), page 1903.

2 "Experiments on the Nature of Ferromagnetism," by F. Bitter, *Physical Review*, Vol. 41 (1932), page 507.

3 "Surface Magnetism in Ferromagnetic Crystals," by L. W. McKeehan and W. C. Elmore, *Physical Review*, Vol. 46 (1934), page 226; Vol. 46 (1934), page 529.

4 "Directions of Discontinuous Changes in Magnetism in Monocrystal Bars and Discs of Silicon-Iron," by R. F. Clash and F. J. Beck, *Physical Review*, Vol. 47 (1935), page 158.

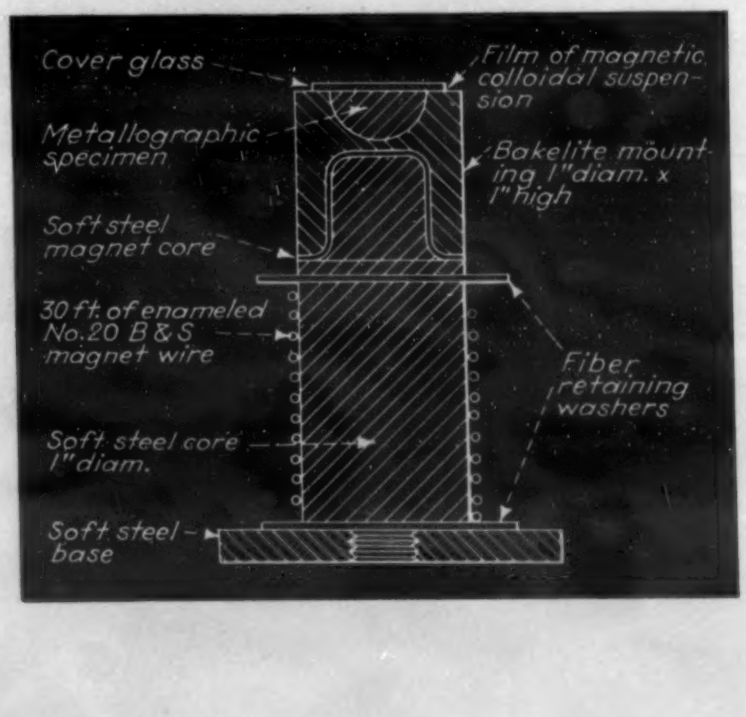
5 "Surface Magnetism and Block Structure of Ferrite," by W. C. Elmore and L. W. McKeehan, *Metals Technology*, Vol. 2, No. 8 (Dec. 1935), or A.I.M.E. Technical Publication No. 656.

6 "Introduction to Ferromagnetism," by F. Bitter, McGraw-Hill Book Company, N. Y. (1937).

7 "Ferromagnetic Colloid for Studying Magnetic Structures," by W. C. Elmore, *Physical Review*, Vol. 54 (1938), page 309.

8 "The Magnetization of Ferromagnetic Colloids," by W. C. Elmore, *Physical Review*, Vol. 54 (1938), page 1092.

Fig. 7.—Electromagnet for producing colloidal magnetic patterns in metallographic specimens.



World Electric Steel Output

—Including Soviet Russia

In our April issue, page 126, we published a brief article—"World Electric Steel Output." At that time data for Soviet Russia were not available. We have received the following communication from a Russian professor of metallurgy which adds Russian data to those we presented, thus expanding the value of the information:

Electric Steel Output of the U.S.S.R.

To the Editor: In your article, "World Electric Steel Output," printed in the April 1939 issue of METALS AND ALLOYS, you cited data covering the expansion of the world production of electric steel for the last 25 years. These data are very interesting because, to a certain extent, they characterize the development of metallurgy in various countries.

Unfortunately the article entirely omitted the great growth of the electrical steel industry in Soviet Russia. The output of electric steel in this country has decidedly expanded during the last few years, and by no means can the world production of electric steel be estimated to any degree of accuracy without taking into account the output of the U. S. S. R.

There had been hardly any development of electrical steel production in Czarist Russia. In 1913 the output of this grade of steel was 3,500 tons. During the World War and the first years after the October Socialistic revolution, the electric steel industry made slow progress. From 3,500 tons in 1913 its output grew only to 11,500 tons in 1928.

The first real progress in electric steel production has been made only since 1927 with the beginning of the first "Five-Year Plan" for the development of Soviet industry. Since then the electric steel output has grown at a very fast and steady rate. In 1932 at the end of the first five-year period, the production of this steel reached 100,900 tons which means a ninefold increase in five years.

During the second five-year plan the production of electric steel steadily grew at the same rapid rate. In the last year of this period (1937) 860,000 tons were made.

As the result of the successful fulfillment of the aims of industrial development of the first and second five-year plan, the U. S. S. R. occupies the first place in the world output of electric furnace steel. The rate of expansion of the electric steel industry has been steadier and greater than in any other country as it has not been hampered by economical crises which are unknown to the socialist industry of the U. S. S. R. [Interesting.] While the production of electric steel in all countries except the U. S. S. R. increased 190 times during the last 25 years, the production in the U. S. S. R. grew 250 times. Since 1929 the world output increased 1.75 times; in the same period Soviet Russia expanded its production 41 times.

In Table I are given data for the production of electric steel in the U. S. S. R. during the last 25 years and its percentage of total steel. In Table II is given the world electric steel output during the last 25 years and the percentage of U. S. S. R. production of the world output. In making out this table the data cited by Mr. Cone were used, corrected by the addition of the electric steel made in U. S. S. R. In Table III world output with Soviet Russia included is assembled.

Moscow Institute of Steel
Moscow, U. S. S. R.

A. M. SAMARIN,
Prof. of Metallurgy.

Table I. Production of Electric Steel in U.S.S.R.

	1913	1929	1934	1935	1936	1937
Total, tons	3,500	18,500	286,000	520,000	845,000	860,000
Electric of total, per cent	0.28	0.39	2.99	4.18	5.15	4.80

Table II. World Production of Electric Steel

	1913	1929	1934	1935	1936	1937
Total, tons	176,246	1,889,765	1,534,654	2,746,431	3,600,468	4,110,499
Electric of world total, per cent	0.2	1.00	18.6	18.9	23.4	20.9

Table III. World Output of Electric Steel in 1937

	Electric Steel Output (tons)	Percentage of Total Steel	Percentage of World Production
U. S. S. R.	860,000	4.80	20.9
United States	845,537	1.67	20.6
Germany	700,369	3.58	17.0
Italy	610,000	29.70	14.8
France	315,990	4.05	7.7
Sweden	253,810	23.20	6.2
United Kingdom	215,400	1.66	5.2
Japan	210,000	3.67	5.0
Canada	55,980	4.14	1.4
Poland	30,000	2.10	0.7
Luxemburg	9,147	0.37	0.2
Belgium	3,200	0.08	0.08
India	1,128	0.02	0.03
Total	4,110,499		

A Poem

We recently received from one of our readers the following poem—Metal—which we are glad to pass on:

Metal

A writhing, molten serpent—hissing steam
In scalding clouds—its trails an eerie glow
Where black Gargantuan shapes move to and fro,
Grotesquely as the monsters of a dream;
Strange creatures, pygmied by the depth and height,
The glare and shadow, of this nether sphere—
Weird glistening half-naked gnomes—appear
And vanish with the fitful livid light:
This is the travail that precedes the birth
of Metal! From this matrix all are born—
The sea's leviathan; the spire, cloud-spanned;
The caterpillar tube that burrows earth;
The web crocheted from Cancer to The Horn;
The shining needle in my lady's hand!

JESSIE WILMORE MURTON,
174 N. Washington Ave., Battle Creek, Mich.